# Highway Wildlife Mitigation Opportunities for The Trans-Canada Highway in the Bow River Valley

August 2012


Prepared by:

MIISTAKIS INSTITUTE

MONTANA STATE UNIVERSITY
Western Transportation Institute

# Highway Wildlife Mitigation Opportunities for the Trans-Canada Highway in the Bow River Valley

Final Report

August 2012

Prepared by:

Tracy Lee, MSc, Miistakis Institute, University of Calgary

Anthony Clevenger, PhD Western Transportation Institute, Montana State University

Robert Ament, MSc, Western Transportation Institute, Montana State University

## Acknowledgements

The authors of this report would like to thank Alberta Ecotrust Foundation for its trust responsibilities for the G8 Funds and their disbursement. In addition, we would like to thank Jon Jorgenson and Scott Jevons from Alberta Environment and Sustainable Resource Development and Melanie Percy from Alberta Tourism Parks and Recreation for providing wildlife-vehicle collision data from 1998-2010.

Cover photo credit: Rob Ament/WTI

## Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official policies of the Western Transportation Institute (WTI), Montana State University (MSU) or the Miistakis Institute, University of Calgary.

This report does not constitute a standard, specification, or regulation.

This document should be cited as:

[Lee T, Clevenger, AP and RJ Ament. 2012. Highway wildlife mitigation opportunities for the TransCanada Highway in the Bow Valley. Report to Alberta Ecotrust Foundation, Calgary, Alberta.]

## TECHNICAL DOCUMENTATION

| | | |
|---|---|---|
| 1. Report No.<br>N/A | 2. Government Accession No.<br>N/A | 3. Recipient's Catalog No.<br>N/A |
| 4. Title and Subtitle<br>Highway Wildlife Mitigation Opportunities for the Trans-Canada Highway in the Bow River Valley | | 5. Report Date<br>August 2012<br>6. Performing Organization Code |
| 7. Author(s)<br>Tracy Lee, Anthony P. Clevenger and Robert J. Ament | | 8. Performing Organization Report No.<br>N/A |
| 9. Performing Organization Name and Address<br>Western Transportation Institute<br>Montana State University<br>P.O. Box 174250<br>Bozeman, MT 59717-4250 | | 10. Work Unit No. (TRAIS)<br>N/A<br>11. Contract or Grant No. |
| 12. Sponsoring Agency Name and Address<br>Alberta Ecotrust – G8 Legacy Grant | | 13. Type of Report and Period Covered<br>Research report,<br>April 2011 – August 2012<br>14. Sponsoring Agency Code<br>N/A |
| 15. Supplementary Notes<br>A PDF version of this report is available from WTI's website at www.westerntransportationinstitute.org | | |

| 16. Abstract | | | |
|---|---|---|---|
| A study of a 39 kilometer section of the Trans-Canada Highway (TCH) directly east of Banff National Park in Alberta, Canada evaluated the best locations to mitigate the effect of the TCH on the local wildlife populations and provide for reductions in wildlife-vehicle collisions (WVCs). In addition, the study conducted cost-benefit analyses to show where investments in mitigation may provide a net savings to society. The total number of WVCs for the study section between 1998 and 2010 was 806 or an average of 62 WVCs per year. This amounts to an average cost-to- society of $640,922 per year due to motorist crashes with large wildlife, primarily ungulates. Results indicate there are ten sites where mitigation measures would address a combination of values: local and regional conservation needs, high WVC rates, land security (can't be developed) where mitigation measures are made, and mitigation options that make good sense and were not engineering challenges. Of the ten mitigation emphasis sites (MES) that were identified, the three with the highest combined values (5=very high; 0=low) were: Kananaskis River Bridge (4.4), Yamnuska Bow Valley East Corridor (4.4) and Heart Creek (4.2). Five of the ten MES had average annual costs exceeding $20,000 per year due to WVCs making each of these an excellent candidate for cost effective mitigation measures. The report provides each MES with its own particular blend of recommendations for how best to mitigate the effect of the TCH on the local wildlife populations. An analysis of a wildlife underpass with fencing at a 3 km section of the TCH within the project area near Dead Man's Flats showed that total WVCs dropped from an annual average of 11.8 pre-construction to an annual average of 2.5 WVCs post-mitigation construction. The wildlife crossings and fencing reduced the annual average cost by over 90%, from an average of $128,337 per year to a resulting $17,564 average per year. | | | |
| 17. Key Words<br>Wildlife–vehicle collisions, highway mitigation, cost-benefit analysis, wildlife corridors, habitat connectivity | | 18. Distribution Statement<br>N/A | |
| 19. Security Classification (of this report) N/A | 20. Security Classification. (of this page)<br>N/A | 21. No. of Pages<br>52 | 22. Price<br>N/A |

# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## EXECUTIVE SUMMARY

The portion of the Trans-Canada Highway (TCH) east of Banff National Park in the Bow River Valley of Alberta is a key access point to the mountain parks of the Canadian Rockies. It also connects Calgary to the various local communities and the Stoney Indian Reserve situated in the surrounding foothills and mountains of this part of the province. The area is rich in wildlife, from carnivores such as black and grizzly bears to a wide variety of ungulates – bighorn sheep, elk, deer and moose – as well as many other smaller mammals. The exurban growth of residences and businesses in the Bow Valley, increased tourism, and the shipping of goods and services over the TCH combine to create high traffic volumes, noise, artificial lighting and other man-made factors that may make it a deadly gauntlet for wildlife to cross and a potential barrier for their movement. This project sought to evaluate the study area's wildlife needs: wildlife corridors, high wildlife-vehicle collision (WVC) zones, and the best locations to place highway mitigation measures. In addition, the study conducted a cost-benefit analysis to show where investments in mitigation may provide a net savings to society.

Within the study area, the 39 kilometer (km) section directly east of the Park, only two underpasses with wildlife fencing have been constructed to mitigate 3 km of the TCH in the Dead Man's Flats area. Thus, most of the study area has not been mitigated for wildlife. Lessons from the TCH within Banff National Park which has received extensive wildlife mitigation measures - overpasses, underpasses, connecting wildlife proof fencing, and escape ramps (jump outs) for wildlife trapped on the highway side of the fence – has demonstrated it is possible to reduce annual WVC rates by over 80 percent while at the same time providing safe passage for all large and medium-sized wildlife species for their migration and movement needs. This provides local information on the types and effectiveness of wildlife mitigation measures for the project area.

Within the 39 km project area, results indicate there are 10 sites where mitigation measures would address a combination of values: local and regional conservation needs, high WVC rates, land security (can't be developed) where mitigation measures are made, and highway mitigation options make good sense and were not engineering challenges. Of the 10 mitigation emphasis sites (MES) that were identified and assessed the three with the highest combined values (5= very high; 0=low) were: Kananaskis River Bridge (4.4), Yamnuska Bow Valley East Corridor (4.4) and Heart Creek (4.2).

The total number of WVCs for the 39 km study section between 1998 and 2010 were 806 or 62 WVCs per year. This amounts to an average cost of $640,922 per year for this segment of the TCH due to motorist crashes with wildlife. Of the ten MES, average annual WVCs varied from a low of 0.31 per year on the kilometer of road surrounding the Kananaskis River Bridge MES to a high of 4.62 WVCs per year on the kilometer of road at the Yamnuska Bow Valley East Corridor MES.

These annual average WVC rates equate to annual costs to society between a low of $2,051 to a high of $48,118.  Five of the ten MESs had average annual costs exceeding $20,000 per year making each of these an excellent candidate for cost effective mitigation measures.

An analysis was possible to evaluate the effectiveness and costs savings of an underpasses with fencing at Dead Man's Flats that was constructed within the project area. WVC data was available at the location for six years, both pre- and post-construction.  Total WVCs dropped from an annual average of 11.8 pre-construction to a six year annual average of 2.5 WVCs post-mitigation construction. From a cost-to-society perspective, mitigation reduced the annual average cost by over 90%, from an $128,337 average per year to a resulting $17,564 average per year.  This 3 km section of the highway within the project area provides local evidence of the effectiveness and cost benefit potential for the ten MESs in this study. Last, this report provides for each MES its own particular blend of recommendations for how best to mitigate the effect of the TCH on local wildlife populations.

# 1. INTRODUCTION

The Bow Valley consists of a complex array of human residential developments and associated land-use activities, a major transportation corridor (Highway 1, the Trans-Canada Highway and the Canadian Pacific railway) and an active rock mining industry. The Trans-Canada Highway (TCH) has been identified as one important barrier to wildlife movement and a source of mortality for wildlife in the region. The purpose of this report is to identify areas along the TCH from the junction of Highway 40 to the Banff National Park (BNP) East Gate where transportation mitigation for wildlife needs to be considered. Transportation mitigation is an important strategy for improving human safety and ensuring connectivity across the TCH for wildlife species. The success of transportation mitigation measures has been well documented as an effective strategy to reduce wildlife-vehicle collisions and facilitate wildlife movement.

Prioritizing highway segments where mitigation needs to be considered is important to assist transportation planners in decision making around mitigation. The species concerned, the nature of the terrain, and the land security (potential for development) all influenced the prioritization of highway segments that could receive mitigation measures. An important concern from transportation planners has been the costs associated with implementing transportation mitigation measures for wildlife. Cost-benefit analyses of mitigation measures allow for insight in the financial aspects of wildlife-vehicle collisions and their mitigation measures. It may also be useful in the potential future decision process on whether to implement mitigation measures.

Specifically the objectives of this project include:

- Identify and prioritize highway segments that may require mitigation measures aimed at reducing wildlife-vehicle collisions (WVCs) and providing safe crossing opportunities for wildlife based on:
    - existing WVC data; and
    - existing reports, maps and local knowledge of important wildlife habitats and wildlife corridors bisected by the TCH.
- Evaluate and rank the priority highway segments, called mitigation emphasis sites (MES), for five transportation and conservation factors via a field assessment.
- Conduct a monetary cost assessment (to society) of the wildlife-vehicle collisions based on published ungulate (moose, deer, elk and bighorn sheep) crash data for the entire 38 kilometers of the TCH within the project area and for each MES.
- Make recommendations for mitigation measures at each mitigation emphasis site based on a field review.
- Provide a cost-benefit analysis of these mitigation measures based on the cost of WVCs and the costs of the recommended measures.

- Within the project area are two existing wildlife underpasses with exclusionary fencing guiding animals to the crossings. Use existing data, where available, to evaluate the pre- and post-construction WVC rates and economic success or failure of the mitigation.

## 2. STUDY AREA

The study area for this project includes a 38 km stretch of the TransCanada Highway (TCH) from the junction of the TCH with Highway 40 to Banff National Park East Gate (Figure 1). This stretch of the TCH runs along a rare east-west corridor, the Bow Valley, within a landscape dominated by north-south mountain ridges in the Canadian Rockies. The Bow Valley represents high quality low elevation wildlife habitat in a mountain landscape where ice and rock are common. The region is both home and a travel corridor for the full complex of Canadian large mammals including grizzly bear, lynx, cougar, wolves, bobcats, wolverine, bighorn sheep, elk, deer and moose.

Much of the Bow Valley is protected, with BNP to the west, and to the east, west and south by the Canmore Nordic Centre, Bow Valley and Spray Valley Provincial Parks. However, in the valley bottom, wildlife in the region competes for space with numerous land uses and activities from the local population and the large urban center of Calgary. The Bow Valley is a beautiful place to live and supports the town of Canmore (17,000 residents and growing) as well as the hamlets of Dead Man's Flats, Lac Des Arcs, Exshaw and Harvie Heights. There is a well development assortment of trails and facilities thorough out the region to support a large recreational tourism industry. Other land-uses include an active rock mining industry, four-lane TCH connecting Canada from the East Coast to the West Coast with annual daily traffic volumes of 21,500 around Canmore and the Canadian Pacific Railway, a two-line railway supporting upward of 40 trains a day. All these activities, changes in land use and natural topography combined to create a complex landscape for wildlife to navigate.

Wildlife research in the area highlights the complexity and limitations of wildlife movement through the Bow Valley due to human activity and natural barriers (Whittington and Forshner 2009, Percy 2003). Therefore reducing WVCs along the TCH and facilitating safe movement across the TCH is an important contribution for maintaining wildlife in the region.

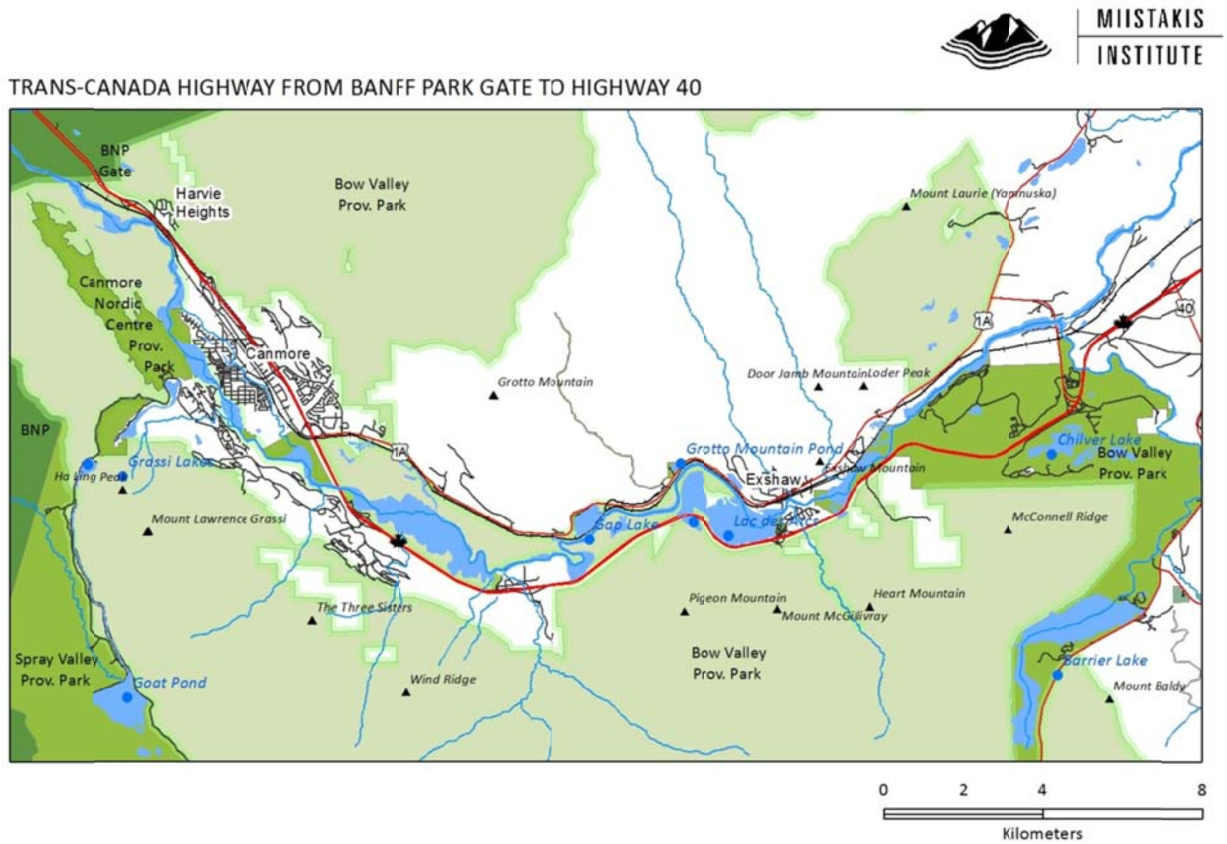


**Figure 1: Map of the study area along the TransCanada Highway (Highway 1) from the east entrance of Banff National Park to junction with Highway 40.**

## 3. WILDLIFE CORRIDORS AND ECOLOGICAL CONNECTIVITY

### 3.1 Ecological Effects of Roads

Roads have increasingly fragmented North America's landscapes over the last 100 years (Ritters and Wickham 2003) and constitute one of the greatest threats to maintaining landscape connectivity and conservation of biodiversity. The primary effects of roads on wildlife include habitat loss, degradation and fragmentation; direct mortality; and road avoidance behaviors (Forman and Alexander 1998). Further, wildlife-vehicle collisions affect the safety of drivers and are costly to society (Huijser et al. 2007, Huijser et al. 2009).

Wildlife populations using areas adjacent to roads face increased mortality risk due to collisions with vehicles (Mumme et al. 2000). A national study identified 21 federally listed threatened or endangered animals in the U.S. for which road mortality is among the major threats to the survival of the species (Huijser et al. 2007).

Adverse road effects are amplified with increasing road size (Fahrig et al. 1995, Lovallo and Anderson 1996), speed limits (Gunther 2000), and traffic volume (Seiler 2003, Waller and Servheen 2005). For every kilometer of highway construction, an estimated 644 hectares of land is converted from its original vegetative cover or made available for further development, resulting in a significant loss of habitat to wildlife (Wolf 1981).

## 3.2 Ecological Connectivity

There is increasing concern about the reduction in connectivity for wildlife across roads. Ecological connectivity is a fundamental principle in the conservation of wildlife, ecosystems, and the native biodiversity they comprise (Crooks and Sanjayan 2006). In a general sense, all animal and plant populations are shaped by, exist and persist because of spatial connections. Habitat connections are needed for mobile animals to move through and survive within resident home ranges. At broader scales, landscape linkages allow individuals to move among core habitat areas, providing stability to regional populations and allowing range peripheries to be occupied through periodic or continual augmentation. The resulting genetic flow across large connected populations also contributes to localized adaptability to a changing environment and helps to ensure that only genes beneficial to individual fitness are expressed. Although ecological connectivity is nebulous without definition as pertaining to species, habitats, spatial and temporal scales, thresholds and risk, the notion of connectivity is nonetheless central to effective conservation planning.

In some parts of North America, roads are an obstacle to maintaining ecological connectivity and may pose a threat to the long-term persistence of key wildlife populations (Noss et al. 1996, Sweanor et al. 2000, Gibbs and Shriver 2002, Epps et al. 2005), and may significantly affect wildlife population demographics (Gibbs and Steen 2005). The habitat fragmentation effects of roads can isolate wildlife populations unwilling or unable to cross roads (Gerlach et al. 2000). It comes as little surprise that the ecological effects of roads are gaining more attention among transportation agencies, land managers, local decision makers and the general public. Today road networks continue to expand and there are increasing public and political concerns regarding transport, ecology, quality of life, and local communities.

Ecological connectivity at a landscape scale is becoming increasingly important in the face of a changing climate (da Fonseca et al. 2005, Heller and Zavaleta 2009). Local-scale corridors such as wildlife crossing structures may play an important role in allowing animals to adapt and respond to a warming climate. Highway mitigation measures that facilitate connectivity and dispersal for fragmentation-sensitive species is needed to ensure local-scale habitat linkages will be able to mitigate continental-scale bottlenecks (Crooks and Sanjayan 2006, Hilty et al. 2006).

## 3.3 Climate Change

Climate change adds to the cumulative impacts on natural systems and wildlife populations by exacerbating the negative effects of habitat loss, degradation, and fragmentation. Local climate disruptions are changing long-term patterns of fire, drought, and flood, as well as seasonal patterns of precipitation and temperature. To adapt and survive, many wildlife species will need to adjust their home ranges and movement patterns. In many cases, fragmentation will impede such adaptation, potentially resulting in isolated wildlife populations that will be highly vulnerable to extirpation or extinction. #

Scientific reviews of the best strategies to protect biodiversity highlight the importance of maintaining landscape connectivity to assure species can move in reaction to climate induced changes (Mawdsley et al. 2009). Another review of 25 years of published literature points out that the most common recommendation to protect biodiversity in the face of climate change was to increase connectivity (Heller and Zavaleta 2009). Lastly, in their review of wildlife corridor studies, Gilbert-Norton et al. (2010) found that corridors increase movement between habitat patches by approximately 50% compared to patches that are not connected with corridors.

Maintaining permeable highways will support animal movement as species seek locales that contain the conditions for which they are adapted. Conserving corridors and maintaining safe wildlife movement is not only strategic and climate smart, but a proven method of allowing wildlife to respond to environmental challenges. Since highway mitigation infrastructure is designed to exist for 50 to 75 years, mitigation measures that are implemented today increase the probability for animals to successfully adjust to changing environmental conditions far in to the future.

A better understanding is needed to properly mitigate the adverse effects that busy roads exert upon local wildlife populations. This information is important for planning and designing wildlife mitigation measures for specific locations to reduce mortality. Equally important is for highways to maintain their permeability for wildlife to facilitate a species' and a population's ability to move and adapt to changing environmental or climatic conditions.

## 3.4 New Direction and Emphases for Highway Mitigation

Most highway wildlife mitigation is focused on providing for the safety of motorists, i.e., addressing problematic wildlife-vehicle collisions areas along highways. As a result, most data collected by transportation agencies are reports on collisions with large mammals, primarily ungulates – deer, Odocoileus sp.; elk, Cervus elaphus; moose, Alces alces and Rocky Mountain bighorn sheep, Ovis canadensis. Since the mission of federal and provincial highway agencies focuses on speed, safety and efficiency; the need to provide for the conservation of wildlife is often an ancillary focus to their primary mission.

However, much progress has been made in the past decade as federal and provincial agencies incorporate ecological connectivity into highway projects. The most famous example is immediately west of the project area in BNP. Over 30 years ago, safety and logistical considerations compelled planners to upgrade the TCH within BNP from 2 to 4 lanes (i.e., twinning), beginning from the eastern boundary of the park and working west (Clevenger and Waltho 2000; McGuire and Morrall 2000).

In each phase, large mammals were excluded from the road with a 2.4-m-high fence erected on both sides of the highway. Underpasses were also built to allow wildlife to cross the road. The first 27 km of highway twinning included 11 wildlife underpasses and was completed by 1988. The next 18 km section was completed in late 1997 with 10 additional wildlife underpasses and two wildlife overpasses (Ford et al. 2010). The final 38 km of twinning to the western park boundary at the Continental Divide and British Columbia-Alberta border will be completed in 2013 and consist of 21 additional wildlife crossing structures, including four 60-m wide wildlife overpasses.

Mitigation efforts during the last 25 years have helped restore habitat connectivity across large sections of this major transportation corridor. The measures have been effective at reducing highway-related mortality of large mammals (Clevenger et al. 2001), contributing to dispersal and gene flow among grizzly (*Ursus arctos*) and black bears (*U. americanus*; Sawaya 2012) and provided evidence-based guidelines for future crossing structure designs in BNP and elsewhere (Clevenger and Waltho 2000, 2005; Clevenger and Huijser 2011).

Another example, the I-90 Snoqualmie Pass East Project, an expansion of an interstate highway in the Cascade Mountains by the Washington State Department of Transportation, has included a desired ecological condition that "requires reducing risks of road-related mortality of wildlife, improving the permeability of the highway for all organisms, and providing for the long-term sustainability of populations in the area" (Clevenger et al. 2008).

This project focused on the provincial section of the TCH east of Banff National Park's boundary. It used wildlife-vehicle collision data as a chief consideration to select mitigation emphasis sites. However, it also used data and maps of wildlife movement across the TCH and other wildlife information to aid in the selection of wildlife mitigation emphasis sites (MESs). Thus, this project has evaluated both wildlife conservation needs and motorist safety needs.to select where mitigation measures should be considered.

## 3.5 Connectivity in the Bow Valley

To determine where wildlife connectivity is important along the TCH, we used the existing wildlife corridors and habitat patches developed by the Bow Corridor Ecosystem Advisory Group (BCEAG) (Figure 2) (BCEAG 1998). In addition, the following reports were considered when identifying the location of MESs;

- Whittington, J. and A. Forshner. 2009. An analysis of wildlife snow tracking, winter transect, and highway underpass data in the eastern Bow Valley. 27pp.
- Heuer K. and T. Lee. 2010. Private land conservation opportunities in the Bow Valley. Prepared for the Yellowstone to Yukon Conservation Initiative (Y2Y), Bow Valley Land Conservancy and Nature Conservancy of Canada. Y2Y offices, Canmore, AB.
- Golder Associates. 2002. Final report: assessment of wildlife corridors within in DC site 1, DC site 3, and District R. Prepared for Three Sisters Resort, Inc. and the Town of Canmore.
- Lee, T., Managh, S. and N. Darlow 2010. Spatial-temporal patterns of wildlife distribution and movement in Canmore's benchland corridor. Prepared for Alberta Tourism, Parks and Recreation, Canmore, Alberta.

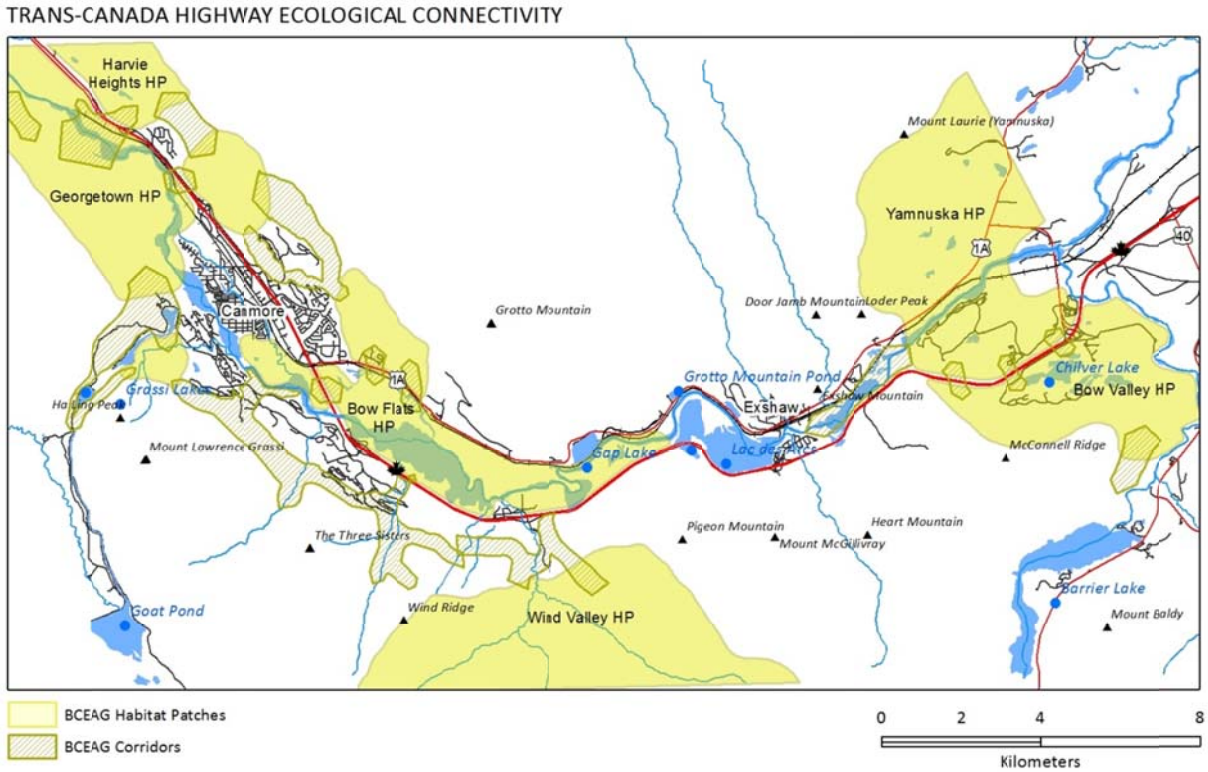


**Figure 2: Map of Bow Corridor Ecosystem Advisory Group's (BCEAG's) habitat patches and wildlife corridors within the Bow Valley.**

## 4. WILDLIFE-VEHICLE COLLISION ASSESSMENT

In this section we highlight the current state of knowledge of wildlife-vehicle collisions (WVCs) along the TCH from the junction with Highway 40 to BNP's East Gate. We identify highway segments (units are in one kilometer sections) where there are high numbers of WVCs. This information was one aspect that was used to help select the highway segments where mitigation should be considered, the project uses the term mitigation emphasis site (MES) for these ten areas.

One of the complexities of quantifying the rate of wildlife mortality from collisions with vehicles along the TCH is the lack of a systematic and standardized data collection system. The data used in this analysis is from 1998-2010, and was acquired from five sources; Table 1 describes the different data collection systems and the years in which the data was collected using these different systems. Each dataset is described in more detail in Appendix A. In addition many of the records where not confirmed by Alberta Environment and Sustainable Resource Development (AESRD) staff and the accuracy of the location is therefore unknown.

**Table 1: Sources of wildlife-vehicle collision data for the project area.**

| Year | Data sources |
|---|---|
| 1998 | Clevenger[1] |
| 1999 | Clevenger, ENFOR[2] |
| 2000 | Clevenger, ENFOR |
| 2001 | Clevenger, ENFOR |
| 2002 | Clevenger, ENFOR, |
| 2003 | Clevenger, ENFOR, WOD[3] |
| 2004 | Clevenger, WOD |
| 2005 | Clevenger, WOD |
| 2006 | KES[4], ENFOR, Logbook[5] |
| 2007 | KES, ENFOR, Logbook |
| 2008 | KES, ENFOR, Logbook |
| 2009 | KES, ENFOR, Logbook |
| 2010 | KES, ENFOR, Logbook |

[1] Clevenger – Data collected by Tony Clevenger systematically from April to October 1998 to 2002. Other months (Nov-March) and from 2003 to 2005 data were collected by Alberta Environment and Sustainable Resource Development (AESRD) Fish and Wildlife.
[2] ENFOR - Enforcement Occurrence Record database, information collected by AESRD Fish and Wildlife Officers and Parks Conservation Officer. When they encounter road kill or respond to a public call about a WVC, the officer is required to fill out an ENFOR Occurrence record.
[3] WOD - Wildlife Observation Database, includes records from public calling in a road kill either directly to Kananaskis Emergency Services (KES) or to the AESRD office. Officers and other staff will also on occasion call in road kill information to KES.
[4] KES - Kananaskis Emergency Services database replaced WOD in 2006.
[5] Logbook - a logbook of road kill information maintained in the AESRD office of records of wildlife sightings and moralities witnessed by staff.

Only one of the systems for a short period of time, collected data systematically, the others are all based on opportunistic sightings and rely on the observations and reporting by concerned local citizens or government staff. This data analysis therefore has the following limitations;

- True rates of WVCs occurring along the TCH in the study area and within each highway segment is unknown; and
- Location error for many of the WVC records is unknown.

It is important to note that the analysis in this report to identity highway segments with mortality clusters assumes that the search and reporting effort for crashes involving wildlife is similar for all road segments concerned. Given the limitations of the dataset, we recommend the initiation of a systematic 3-year wildlife survey of the TCH to help improve our understanding of the rates and locations of WVCs.

## 4.1 Data Analysis Methodologies

Data was provided by Alberta Environment and Sustainable Resource Development (AESRD), Fish and Wildlife and Alberta Parks in 2 datasets; 1998-2005 and 2006-2010. The data sets were cleaned (duplicates removed and locations added) by AESRD or Alberta Parks personal. Further cleaning and merging of the datasets for this project are described in Appendix A.

Data was processed to generate the average number of WVCs for this 39 km stretch of TCH, as well for each species including both known and unknown locations. These numbers (known and unknown) were used to calculate an annual rate of WVCs, species involved in WVCs and a conservative estimate of the total costs of ungulate vehicle collisions for this the section of the TCH in the project area.

### *4.1.2 Mortality Clusters*

To identify highway segments where WVCs mortality clusters occur, the TCH was divided into one kilometer (km) segments. Known WVC location data was enumerated to each km section along TCH. A moving window approach was used to calculate a mortality value for each segment, where by each segment was equated to a sum of itself and its two neighbouring segments. Therefore, the wildlife mortality value was representative of a 3-km long section “moving window”.

Mortality values were classified using a quintile approach, whereby segments with zero were removed from the analysis and segments with mortality values were categorized into percentiles where “very high” represents the 81-100 percentile (top 20% of WVCs), “high” represents the 61-80 percentile and “medium” are WVC annual rates within the 41-60 percentile.

The method to identify mortality clusters is simply based on identifying the highway segments that have the highest frequency of wildlife-vehicle crashes. The mortality clusters that are identified do not necessarily meet a national standard or provincial norm. The procedure described above only identifies the road sections with most wildlife vehicle collisions for the highway segments along the TCH included in the analysis. Wildlife-vehicle collisions also occur outside of the mortality clusters, but less frequently.

## 4.2 Results

### 4.2..1 Annual Rate of WVCs Along the TCH

The average number of WVCs recorded on the TCH from Highway 40 to BNP East Gate, a 39 km stretch, is approximately 70 wildlife mortalities annually (Figure 3). The actual mortality rate is likely higher due to a number of factors reducing observer's ability to record all mortalities associated with WVCs. For example, injured wildlife may move away from the road, vegetation may obscure the carcass, a predator or human may remove the carcass from the roadway before it is recorded. It is therefore likely that the datasets used in this analysis are in-accurate in terms of magnitude of the number of wildlife mortalities occurring along the TCH.

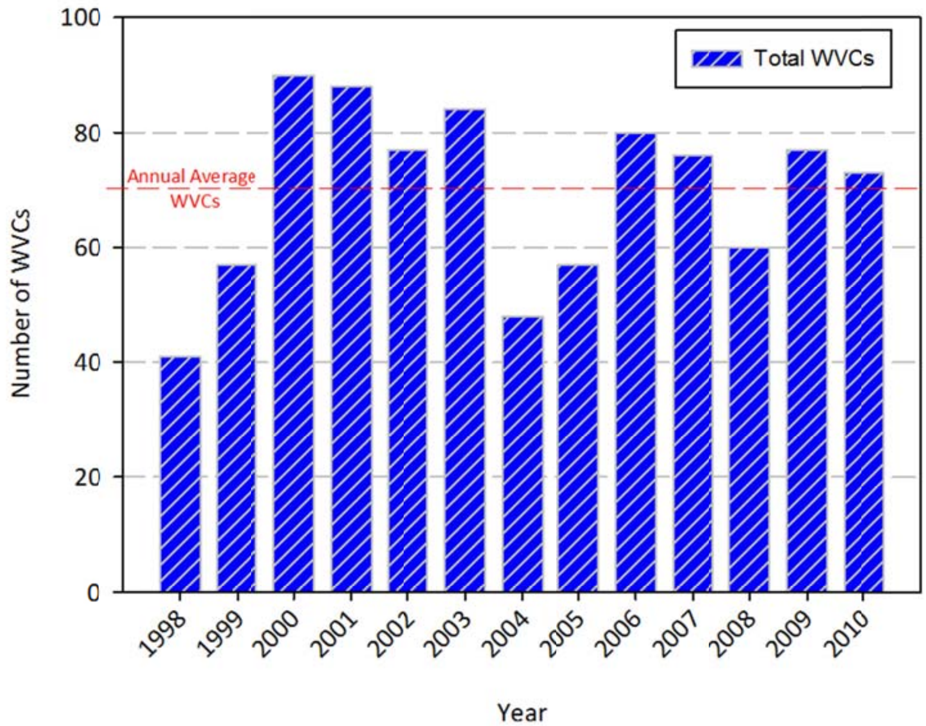


**Figure 3: Total number of wildlife-vehicle collisions (WVCs) on the TransCanada Highway in the project area.**

Wildlife vehicle collisions with large mammals predominately involve deer (58%) and elk (33%) and to a lesser extent moose (2%), bighorn sheep (2%), black bear (4%) and cougars (1%).

### 4.2.2 High Collision Zones Along the TCH

The identification of highway segments (1-km in length) classified into percentiles of very high, high and medium wildlife mortality rates are displayed in Figure 4. Along the TCH, seven kilometers of the highway were classified as *very high* mortality clusters, representing 18% of the study area, while 15 km of the highway were classified as *high* mortality clusters and represented 22% of the Highway in the study area (Figure 4).

It is difficult to compare the rates of WVCs along this section of the TCH with other areas in the province of Alberta's transportation system due to inconsistencies in data collection across the province.  Alberta Transportation may want to consider developing a consistent data collection methodology for the province that would enable a review of the very high to medium wildlife vehicle collision zones from a provincial perspective and enable planners and decision makers to better prioritize transportation mitigation strategies across the province. Only highway segments within the top 40% percentile (high and very high) of WVC's were considered in the identification of site specific mitigation sites along this stretch of the TCH.

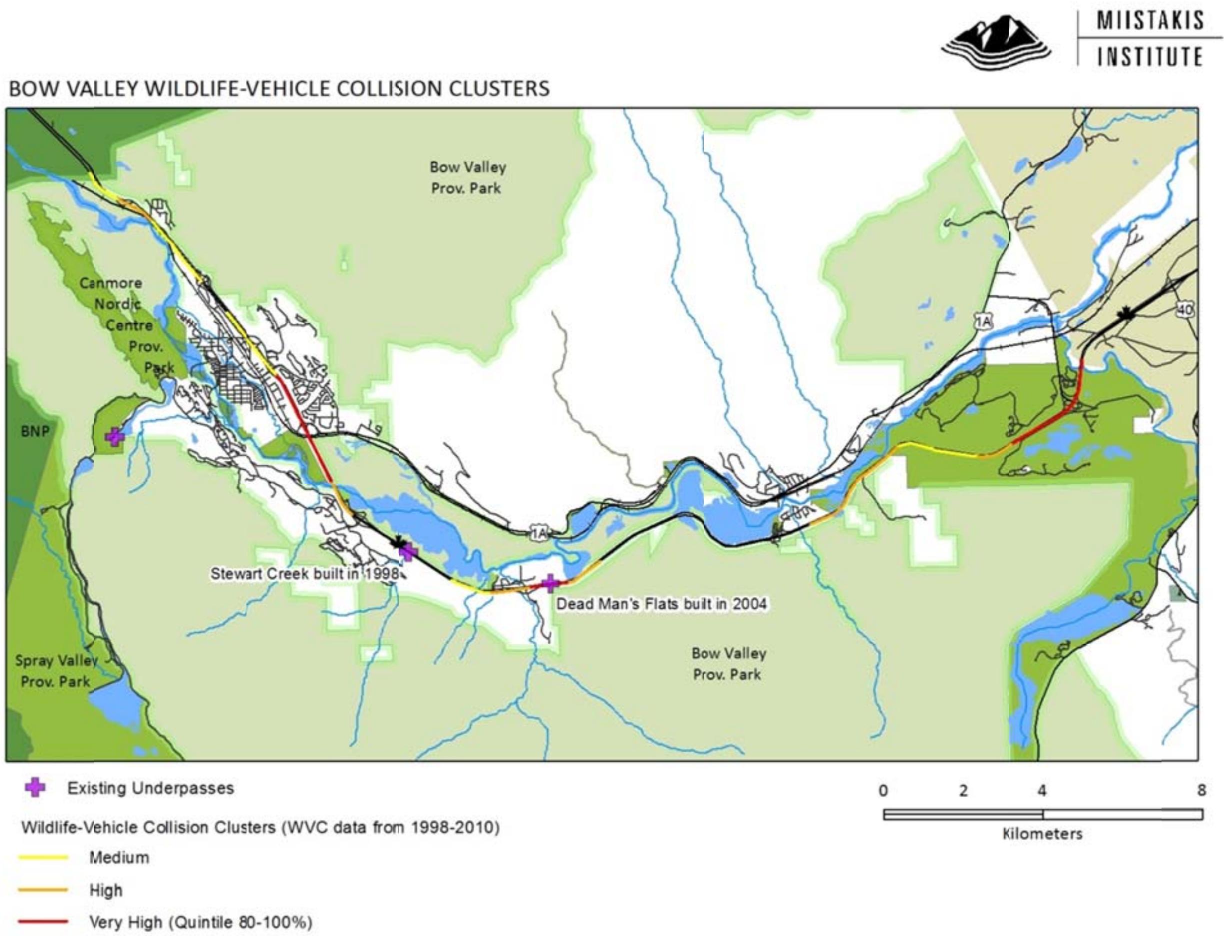


**Figure 4: Wildlife-vehicle collision clusters of medium, high to very high crash rates (those in the 41-60, 61-80 and 81-100 percentile groups, respectively) on the TransCanada Highway within the project area.**

# 5. MITIGATION EMPHASIS SITES

## 5.1. Locations of Mitigation Emphasis Sites

One of the objectives of this project was to identify sites within the study area that are important for wildlife conservation; such as wildlife movement corridors, areas of high mortality due to WVCs and areas where land-use was compatible with investments to mitigate the highway to increase permeability for wildlife. A review of morality clusters and a synthesis of research on wildlife connectivity sites were assessed by the research team and 10 mitigation emphasis sites (MESs) were identified (Figure 5). In addition, a histogram of the annual rate per kilometer highlights the high wildlife mortality clusters addressed by the MESs (Figure 6). Each MES was appraised for its appropriate location and then tested for its inclusion into the study via a field review.

The 10 MESs fall within broader linkage areas along the TCH and where appropriate their assessment considered mitigation strategies for the MES in this broader context. Linkages areas were identified by considering BCEAG developed habitat patches or corridor locations and their intersection with the Highway (Figure 2).

- Yamnuska Linkage – This linkage is from Kananaskis River Bridge to west edge of Bow Valley Provincial Park Linkage, it connects the Yamnuska Habitat Patch to the north with the Bow Valley Habitat Patch to the south. It includes four of the MESs, Kananaskis River Bridge, Yamnuska Bow Valley East, Yamnuska Bow Valley Center and Yamnuska Bow Valley West.

- Heart Linkage – This linkage is from Lac Des Arc to Heart Creek. There are two MESs including Yamnuska Lac Des Arc and Heart Creek.

- Bow Flats Linkage- This linkage is a short stretch between the Bow River Bridge to Junction of Highway 1A and TCH Linkage, occurring within the Bow Valley Flats habitat patch. There are 2 MESs within this linkage including Bow River Bridge and South Canmore Flats.

- Georgetown - Harvie Heights Linkage – This linkage is from Georgetown corridor to the BNP East Gate and includes connects Harvie Heights habitat patch to the north with Georgetown habitat patch to the south. There are two MESs including Georgetown Corridor and Georgetown-Harvie Heights.

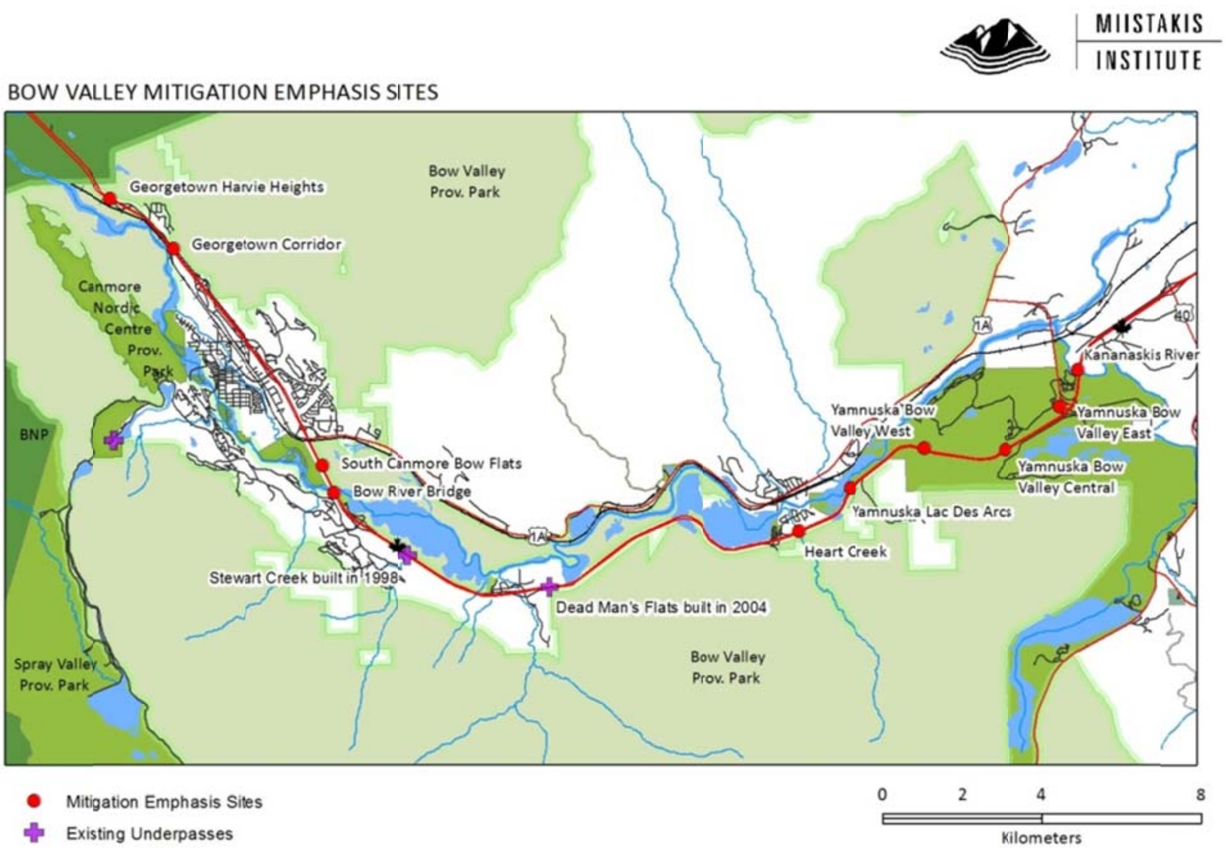


**Figure 5: The ten mitigation emphasis sites (red dots) that were selected along the TransCanada Highway within the project area.**

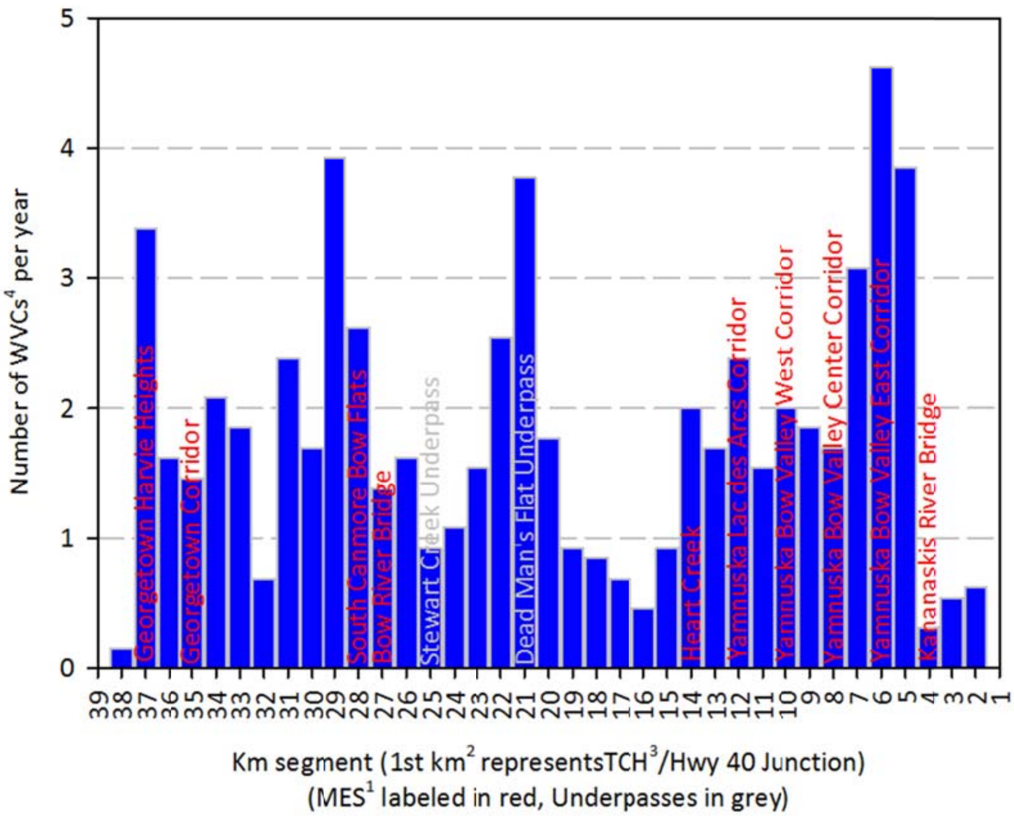


**Figure 6: Annual rate of wildlife-vehicle collisions per one kilometer segments on the TransCanada Highway (TCH), from its junction with Highway 40 to Banff National Park's (BNP) East Gate (right edge is the junction of Highway 40 with the TCH and the left edge is BNP East Gate). The underpasses already developed along the TCH are depicted in light grey. [1]MES: mitigation emphasis site; [2]km: kilometer; [3]TCH: TransCanada Highway; [4]WVCs: wildlife-vehicle collisions**

## 5.2. Prioritizing Mitigation Emphasis Sites

A ranking system was developed to help prioritize MES locations with the most importance and potential for wildlife mitigation. We assigned each MES with a subjective score from 1 (low) to 5 (high) based on five criteria at the site: local and regional conservation values, ease of implementing effective mitigation measures, the WVC rates at and adjacent to the site and whether highway mitigation investments were wise based on whether land on both sides of the MES was vulnerable to commercial or residential development.

1. Local Conservation Value - captures the importance of maintaining connectivity for the seasonal movement of local herds of ungulates, carnivores or other related fine scale opportunities for wildlife. For example, elk herds move in the autumn from their summer range at higher elevations in the adjacent mountains down into the valley where the TCH is located for winter.

2. Regional Conservation Significance - captures the importance of the site in maintaining connectivity at a regional scale. This relates especially to large mammals that have low population density (e.g. grizzly bears, wolverines [*Gulo gulo*]), but it could also relate to the importance of corridors for more common species. Success for some of these species may be measured by safe passage at highway crossings at very low rates; since effective population levels are so low.

3. Transportation Mitigation Opportunity - considers the ease of implementing mitigation measures, including consideration of geographical setting and features (i.e, stream crossing, terrain, slope stability), the difficulty or ease for the placement and design of infrastructure (i.e., underpass, overpass), the age, condition and appropriate size of existing infrastructure (i.e., culverts, bridges) and other physical, biological and social (i.e., recreational trails) features. Geotechnical information and other engineering studies were not available during the development of these values in the field.

4. Highway Mortality - the relative rate of WVCs at each site was scaled as a proxy for safety risks to motorists and wildlife. A review for each MES based on annual WVC rates is shown in Figure 4.

5. Land Security - evaluates the condition of the lands directly adjacent to the MES. Investing in highway infrastructure that provides safe passage for wildlife is often an expensive undertaking, costing a million dollars or more. Therefore, land security (protection from development or land uses not conducive to wildlife movement) around the structure is an important consideration. Values for land security were developed based on land ownership, existing conservation easement information, and land development attributes on both sides of the highway at each MES. The highest value (5) was very secure and the lowest value (1) had development on lands on both sides of the highway at the MES location:

- 5 - public lands (federal, provincial, municipal) or private lands with a conservation easement on both sides of MES
- 4 - public lands or conservation easement on one side of MES, open space on the other (with unsecured easements)
- 3 - open space lands on both sides, but unsecured conservation easements for these private lands
- 2 - housing development or industrial/commercial site on one side, open space on other side (with unsecured easements)

- 1 - housing development or industrial/commercial sites on both sides of highway at MES

## 5.3 Results

All 10 mitigation emphasis sites were visited by the project team on 12 April 2012. Table 1 summarizes the values for each site and allows comparison of values between the 10 MESs. Two sites tied for the highest rating (4.4) – Kananaskis River Bridge and Yamnuska Bow Valley East Corridor, both these MESs occur in the Yamnuska Linkage and are the two most eastern MESs in the study area and closest to the junction between Highway 40 and the TCH. Two MESs tied for the lowest average value at 3.2: a) Heart Creek primarily due to low land use security adjacent to the highway and low local conservation value and b) Georgetown Corridor due to difficulties with highway mitigation options near the approach to BNP's East Gate where the TCH pavement is greater than an estimated 100 meters and there are concrete median barriers separating the east- and west-bound lanes (Figure 7).

**Table 2: Relative values of each mitigation emphasis site in the project area, between 0 (low) and 5 (high).**

| MITIGATION EMPHASIS SITE | LOCATION[1] East | LOCATION[1] North | FOCAL SPECIES | LOCAL CONSERVATION VALUE | HIGHWAY MORTALITY | TRANSPORTATION MITIGATION OPTIONS | REGIONAL CONSERVATION SIGNIFICANCE | LAND USE SECURITY | AVERAGE |
|---|---|---|---|---|---|---|---|---|---|
| Kananaskis River Bridge | 636223 | 5661201 | Multiple | 4 | 5 | 5 | 4 | 4 | 4.4 |
| Yamnuska Bow Valley East Corridor | 635770 | 5660280 | Multiple | 5 | 5 | 2 | 5 | 5 | 4.4 |
| Yamnuska Bow Valley Center Corridor | 634400 | 5659203 | Multiple | 5 | 3 | 2 | 5 | 5 | 4.0 |
| Yamnuska Bow Valley West Corridor | 632365 | 5659234 | Multiple | 4 | 3 | 4 | 2 | 5 | 3.6 |
| Yamnuska Lac de Arcs Corridor | 630512 | 5658227 | Carnivores | 3 | 4 | 4 | 5 | 5 | 4.2 |
| Heart Creek | 629212 | 5657152 | Multiple | 2 | 4 | 5 | 3 | 2 | 3.2 |
| Bow River Bridge | 617529 | 5658112 | Multiple | 5 | 2 | 5 | 3 | 4 | 3.8 |
| South Canmore - Bow Flats Corridor | 617241 | 5658787 | Multiple | 5 | 4 | 4 | 3 | 4 | 4.0 |
| Georgetown Corridor | 613508 | 5664256 | Ungulates | 4 | 4 | 1 | 3 | 4 | 3.2 |
| Georgetown-Harvie Heights | 611931 | 5665510 | Multiple | 4 | 5 | 1 | 3 | 5 | 3.6 |

[1] Location values are in UTM, Zone 11.


**Figure 7: The Georgetown-Harvie Heights mitigation emphasis site along the TransCanada Highway near the east entrance to Banff National Park. Collisions with wildlife are very high at this location but the potential mitigation options are extremely limited or very expensive to cover such a wide expanse of roadway.**

## 6. COSTS OF WILDLIFE-VEHICLE COLLISIONS WITH LARGE UNGULATES

Huijser et al. (2009) summarize the costs of the most prevalent group of large mammals—deer, elk, moose—that are involved in over 90 percent of the WVCs in North America (Table 3). All three species are ungulates and are present along the TCH corridor in the project area and have been recorded in the mortality databases. Although Huijser et al. (2009) developed monetary costs in 2007 U.S. dollars, for the purposes of this report it is reported at a par exchange rate in 2007 Canadian dollars. For the purposes of this project's cost analyses, we used the cost of an average collision of deer as representative of bighorn sheep since the two species have relatively similar body sizes and they are more comparable in size than to elk or moose. This is a conservative estimate of the monetary value as the hunting value of bighorn sheep is much higher than for deer.

There have been no average costs of collisions estimated for large carnivores, such as bears or cougars, *Puma concolor*. Therefore our costs to society for the collisions with large mammals at each of the TCH mitigation emphasis sites and across the entire project area are definitely lower than actual monetary costs of WVCs.

**Table 3: Average costs of wildlife-vehicle collisions for 3 common ungulates (from Huijser et al. 2009).**

| **Description** | **Deer** Dollars (2007) | **Elk** Dollars (2007) | **Moose** Dollars (2007) |
|---|---|---|---|
| Vehicle repair costs per collision | $2,622 | $4,550 | $5,600 |
| Human injuries per collision | $2,702 | $5,403 | $10,807 |
| Human fatalities per collision | $1,002 | $6,683 | $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 average cost per collision | $6,617 | $17,483 | $30,760 |

## 6.1. Costs of Wildlife Vehicle Collisions for the Ten MESs

The average collisions rates for the four ungulate species in the project area were calculated for each of the mitigation emphases sites (Table 4). The totals for each MES are based on the recorded WVCs by species within the kilometer section that the MES is located.

**Table 4: Average annual wildlife-vehicle collision rates for each kilometer of the TransCanada Highway within the project area (each mitigation emphasis site is highlighted in yellow).**

| Mitigation Emphasis Site | Average annual wildlife vehicle collision rates (number/km/year) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Km | Elk | Deer | Bighorn Sheep | Moose | Other | Total |
| | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 2 | 0.00 | 0.38 | 0.00 | 0.00 | 0.23 | 0.62 |
| | 3 | 0.00 | 0.46 | 0.00 | 0.00 | 0.08 | 0.54 |
| Kananaskis River Bridge | 4 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 0.31 |
| | 5 | 1.08 | 2.38 | 0.00 | 0.00 | 0.38 | 3.85 |
| Yamnuska Bow Valley East Corridor | 6 | 1.62 | 2.62 | 0.00 | 0.08 | 0.31 | 4.62 |
| | 7 | 1.38 | 1.31 | 0.00 | 0.00 | 0.38 | 3.08 |
| Yamnuska Bow Valley Centre Corridor | 8 | 0.92 | 0.69 | 0.00 | 0.00 | 0.08 | 1.69 |
| | 9 | 0.46 | 1.08 | 0.00 | 0.00 | 0.31 | 1.85 |
| Yamnuska Bow Valley West Corridor | 10 | 0.77 | 0.92 | 0.00 | 0.15 | 0.15 | 2.00 |
| | 11 | 0.15 | 0.92 | 0.00 | 0.08 | 0.38 | 1.54 |
| Yamnuska Lac des Arcs Corridor | 12 | 0.54 | 1.15 | 0.00 | 0.08 | 0.62 | 2.38 |
| | 13 | 0.46 | 0.85 | 0.00 | 0.00 | 0.38 | 1.69 |
| Heart Creek | 14 | 0.23 | 1.54 | 0.08 | 0.00 | 0.15 | 2.00 |
| | 15 | 0.15 | 0.46 | 0.00 | 0.00 | 0.31 | 0.92 |
| | 16 | 0.00 | 0.08 | 0.15 | 0.00 | 0.23 | 0.46 |
| | 17 | 0.23 | 0.38 | 0.00 | 0.00 | 0.08 | 0.69 |
| | 18 | 0.46 | 0.15 | 0.00 | 0.00 | 0.23 | 0.85 |
| | 19 | 0.23 | 0.38 | 0.00 | 0.15 | 0.15 | 0.92 |
| | 20 | 0.15 | 0.54 | 0.85 | 0.00 | 0.23 | 1.77 |
| | 21 | 1.85 | 1.31 | 0.00 | 0.23 | 0.38 | 3.77 |
| | 22 | 0.62 | 1.23 | 0.00 | 0.15 | 0.54 | 2.54 |
| | 23 | 0.38 | 0.77 | 0.00 | 0.08 | 0.31 | 1.54 |
| | 24 | 0.15 | 0.85 | 0.00 | 0.00 | 0.08 | 1.08 |
| | 25 | 0.08 | 0.31 | 0.15 | 0.00 | 0.38 | 0.92 |
| | 26 | 0.15 | 0.77 | 0.23 | 0.08 | 0.38 | 1.62 |
| Bow River Bridge | 27 | 0.38 | 0.38 | 0.00 | 0.00 | 0.62 | 1.38 |
| South Canmore - Bow Flats Corridor | 28 | 1.31 | 0.92 | 0.00 | 0.00 | 0.38 | 2.62 |
| | 29 | 2.38 | 1.23 | 0.00 | 0.00 | 0.31 | 3.92 |
| | 30 | 0.62 | 0.92 | 0.00 | 0.00 | 0.15 | 1.69 |
| | 31 | 0.85 | 1.23 | 0.00 | 0.00 | 0.31 | 2.38 |
| | 32 | 0.08 | 0.46 | 0.00 | 0.00 | 0.15 | 0.69 |
| | 33 | 0.46 | 1.23 | 0.00 | 0.00 | 0.15 | 1.85 |
| | 34 | 0.46 | 1.38 | 0.00 | 0.00 | 0.23 | 2.08 |
| Georgetown Corridor | 35 | 0.23 | 1.00 | 0.00 | 0.00 | 0.23 | 1.46 |
| | 36 | 0.62 | 0.69 | 0.00 | 0.00 | 0.31 | 1.62 |
| Georgetown-Harvie Heights | 37 | 1.31 | 1.38 | 0.15 | 0.00 | 0.54 | 3.38 |
| | 38 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| | 39 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Based on the average WVC rates in Table 4 and the average costs to society for each species from Table 3, the average annual costs of ungulate-vehicle collisions (UVCs) at each MES are calculated and reported in Table 5.

**Table 5: Average annual costs of ungulate-vehicle collisions at the ten mitigation emphasis sites on the TransCanada Highway within the project area.**

| Mitigation Emphasis Site Name | Annual Average Ungulate-Vehicle Collision Costs (in 2007 Canadian Dollars) | | | | |
|---|---|---|---|---|---|
| | Elk | Deer | Bighorn Sheep | Moose | Total |
| Kananaskis River Bridge | $0 | $2,051 | | | $2,051 |
| Yamnuska Bow Valley East Corridor | $28,322 | $17,337 | | $2,460 | $48,119 |
| Yamnuska Bow Valley Center Corridor | $16,084 | $4,566 | | | $20,650 |
| Yamnuska Bow Valley West Corridor | $13,462 | $6,088 | | $4,614 | $24,164 |
| Yamnuska-Lac de Arcs Corridor | $9,441 | $7,610 | | $2,461 | $19,512 |
| Heart Creek | $4,021 | $10,190 | $529 | | $14,740 |
| Bow River Bridge | $6,644 | $2,514 | | | $9,158 |
| South Canmore-Bow Flats Corridor | $22,903 | $6,088 | | | $28,991 |
| Georgetown Corridor | $4,021 | $6,617 | | | $10,638 |
| Georgetown-Harvie Heights | $22,903 | $9,131 | $993 | | $33,027 |

Table 5 indicates that many of the MESs have elevated annual costs of crashes with wildlife due to the high rates of crashes with ungulates. The most expensive site is Yamnuska Bow Valley East Corridor, with a total exceeding $48,000 per year. Of the ten MES, only two are less than $10,000 per year. One half of the ten sites exceed $20,000 per year. These relatively high monetary values indicate that mitigation measures, such as wildlife underpasses with fencing, could prove to be not only biologically effective in reducing WVCs, but could easily be cost effective as well.

## 6.2. Costs of Wildlife-Vehicle Collisions for the Project Area

The cumulative WVCs for the project area are summarized in Table 6 for the six large mammals that were in the various data sets (refer to Section 4 for discussion of data). These totals include both MESs and highway segments outside the MESs. A total of 806 dead wildlife were recorded in the data sets for the 39 kilometers of the TCH area over a 13-year period, from 1998-2010. These WVCs result in an average of 62 collisions (includes only WVCs of known location) with large mammals per year in the project area (Table 6). Since only the average annual costs to society for UVCs can be calculated, the large number of UVCs results in an average cost of $640,922 per year for these crashes within the project area. A decadal conservative value would put the cost of UVCs at nearly 6 ½ million dollars for this 39 km stretch of the TCH.

Table 6: Annual rates of wildlife-vehicle collisions by species and costs of ungulate-vehicle collisions on thirty-nine kilometers of the TransCanada Highway within the project area.

| Annual wildlife-vehicle collisions and costs (based on crash data from 1998-2010) | Species | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Deer | Elk | Moose | Bighorn sheep | Black bear | Cougar | |
| Total number of collisions | 467 | 267 | 15 | 17 | 32 | 8 | 806 |
| Annual wildlife-vehicle collision rates | 35.9 | 20.5 | 1.2 | 1.3 | 2.5 | 0.6 | 62 |
| Annual wildlife-vehicle collision costs | $237,703 | $359,074 | $35,492 | $8,653 | 0 [1] | 0 [1] | $640,922 |

[1] The average costs for carnivore-vehicle collisions have not been determined.

## 7. MITIGATION SUCCESS STORY: THE DEAD MAN'S FLATS UNDERPASS

The Dead Man's Flats underpass and exclusionary fencing was completed in 2004. Figure 3 displays the location of the Dead Man's Flats underpass along the TCH (purple cross). Figure 4 displays the number of WVCs per year occurring within a 1.5 km stretch east and 1.5 km west of the underpass site. The average number of WVCs prior to the construction of the underpass was 11.8 annually based on six years of the dataset (1998-2003). After completion of the underpass and fencing mitigation in 2004, the average number of WVCs dropped significantly to 2.5 per year based on 6 years of the data (2005-2010).

### 7.1 WVCs Pre- and Post-construction around the Dead Man's Flats Wildlife Underpass Structure and Fencing

In 2004, the Dead Man's Flats underpass and wing fencing (purple cross located on Figure 1) was completed on the TCH. The mortality cluster analysis identified a very high mortality cluster on the highway segment where the Dead Man's Flat's underpass is located (Figure 5). To assess the effectiveness of the underpass and fencing in reducing WVCs at this location, data was divided into pre-construction of the underpass (1998-2003) and post- construction of the underpass (2005-2010) for the one kilometer of highway where the underpass is located and both neighbouring one kilometer sections, for a total of 3 kilometers of the TCH surrounding the Dead Man's Flats wildlife underpass. Data from 2004 was removed as the underpass was built in 2004. A t-test was run to determine if the number of WVCs pre- and post-construction are statistically different. In addition, for the rest of the TCH, excluding Dead Man's Flats 3 km section was statistically compared for the number of WVCs between the two time spans. This will enable us to determine if changes at Dead Man's Flats in the number of WVCs is due to an overall reduction in number of WVCs occurring along the TCH. In addition, pre- and post-construction costs of UVCs were compared using the average monetary costs of UVCs by species, from Table 2.

## 7.2 Results

Figure 6 summarizes the total number of WVCs per year for the 3 kilometer section of the TCH surrounding the Dead Man's Flats underpass, from a high of 19 WVCs in 2002 to a low of zero WVCs in 2005.

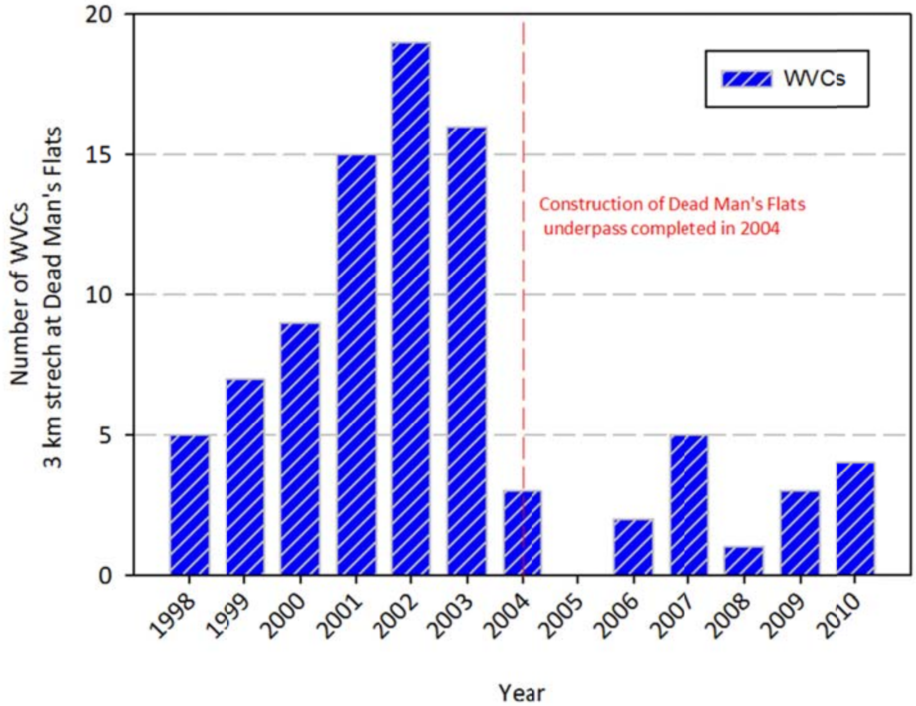


**Figure 4: Number of wildlife-vehicle collisions per year along the three kilometers of the TransCanada Highway centered at the Dead Man's Flats wildlife underpass.**

### *7.2.1 Statistically Significant Reduction in WVCs*

The WVC numbers are very stark at Dead Man's Flats before the underpass was built and after the underpass was constructed with fencing. No single year previous to the mitigation had less than five WVCs, while after the mitigation was implemented, no single year exceeded five WVCs (Figure 4). This represents a 78.8% reduction in WVCs in the TCH segment with the underpass and fencing installed at Dead Man's Flats. A t-test of the pre- and post-construction data confirmed that the WVCs post-construction were significantly less statistically (results of two-tailed t-test, P value= 0.0075) than the pre-construction WVCs.

The rest of the TCH study area where there was not mitigation (excluding three km at Dead Man's Flats) was analysed. There was no statistical difference in the number of WVCs (results of two-tailed t-test, P value = 0.2540) between the 1998-2003 and 2005-2010 time spans. Therefore, statistical results highlight the reduction in WVCs at Dead Man's Flats underpass is the highly probable result of the construction of the underpass with wildlife fencing.

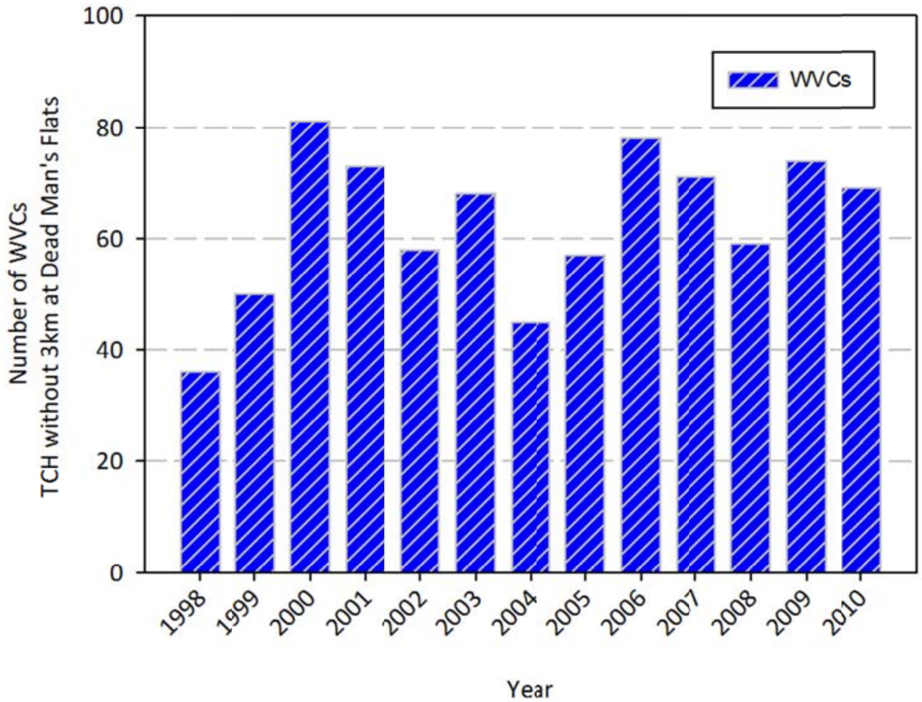


**Figure 5: Summary of total number of recorded wildlife-vehicle collisions per year along the TransCanada Highway in the project area, excluding the 3 km section at Dead Man's Flats.**

### *7.2.2 Significant Cost Savings from WVC Reductions*

To determine a very conservative estimate of the cost savings due to the reduction in WVCs occurring at this site, the monetary value of ungulate species was calculated pre- and post-construction of the Dead Man's Flats underpass. The annual monetary cost of WVCs associated with crashes before construction was $128,300 annually. This was reduced to annual monetary costs of $17,500 in WVCs following the construction of the Dead Man's Flats underpass (Table 7).

**Table 7: Costs of ungulate-vehicle collisions (UVCs) before and after construction of a wildlife underpass and fencing of the TransCanada Highway at Dead Man's Flats.**

| Species | Pre-construction WVCs 1998-2003 | Cost of UVCs[1] | Post-construction WVCs 1005-2010 | Cost of UVCs[1] |
|---|---|---|---|---|
| Deer | 30 | $198,510 | 8 | 52,936 |
| Elk | 22 | $384,626 | 3 | 52,449 |
| Moose | 5 | $153,800 | 0 | 0 |
| Bighorn Sheep | 5 | $33,085 | 0 | 0 |
| Coyote | 5 | $0 | 0 | 0 |
| Wolf | 2 | $0 | 0 | 0 |
| Cougar | 1 | $0 | 0 | 0 |
| Black Bear | 0 | $0 | 2 | 0 |
| Beaver | 0 | $0 | 2 | 0 |
| Unknown | 1 | $0 | 0 | 0 |
| Total WVCs and Costs of the UVCs | 71 | $770,021 | 15 | $105,385 |
| Annual WVC Rates and Costs | 11.8 | $128,337 | 2.5 | $17,564 |

[1] Only the average costs of vehicle collisions with ungulate species have been determined, estimations for carnivores have not been derived and thus do not have a monetary value in this analysis (see Huijser et al. 2009).

## 8. COST EFFECTIVENESS OF MITIGATION MEASURES

For mitigation measures to be cost-effective there needs to be a break-even point or a dollar value threshold where the investment in the mitigation measure equals or is below the average annual costs of the WVCs at the mitigation site. Huijser et al. (2009) thoroughly detailed these values for deer, elk and moose in North America. The number of deer, elk, and moose-vehicle collisions kilometer$^{-1}$ year$^{-1}$ 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 (see Table 8). The threshold value for less costly mitigation of fencing, jump-outs and wildlife underpasses, however, is 3.2 deer–vehicle collisions per kilometer per year. Because we know the cost of different mitigation measures per year and their effectiveness at reducing WVCs, we can calculate the break-even point for any recommendations of different wildlife mitigation measure on the TCH in the study area based on their cost thresholds (Table 8).

**Table 8: Effectiveness, cost threshold values, and deer-vehicle collision rates to meet or exceed those cost effectiveness thresholds (adapted from Huijser et al. 2009).**

| Wildlife Mitigation Measure | Effectiveness of Measure (average percent reduction in wildlife-vehicle collisions) | Cost Threshold (2007 Dollars) | Annual Deer-Vehicle Collision Rate: to meet or exceed cost threshold (deer/kilometer/year) |
|---|---|---|---|
| Fencing | 86 | $6,304 | 1.1 |
| Fencing, underpass, jump outs[1] | 86 | $18,123 | 3.2 |
| Fencing, over- and underpass, jump outs | 86 | $24,230 | 4.3 |
| Animal detection system (ADS) | 87 | $37,014 | 6.4 |
| Fencing, gap, ADS, jumpouts | 87 | $28,150 | 4.9 |
| Elevated roadway | 100 | $3,109,422 | 470 |
| Submerged roadway (underground tunnel) | 100 | $4,981,333 | 753 |

[1] Jump-outs are “escape ramps” that let wildlife inadvertently trapped on the highway side of the fencing to jump out to safety.

There are other wildlife mitigation measures but most are far less effective in reducing WVCs than the ones listed in Table 8. For example, seasonal wildlife warning signs for motorists only reduce WVCs by an average of 26% or relocating wildlife reduces WVCs by an average of 50 percent (Huijser et al. 2009). Thus Table 8 only lists those wildlife mitigation measures that are proven to reduce WVCs by greater than 80 percent.

Based on the calculated annual average costs of ungulate-vehicle collisions for each mitigation emphasis site (Table 5) it appears that 6 of the 10 MESs exceed $19,500. Therefore, due to the effectiveness of fencing and underpasses with jump-outs, any MES that exceeds $18,123 (Table 8) would be able to reduce WVCs at the site by over 85% and still be cost effective using that mitigation measure. MESs that exceeds average annual costs of $24,230 would most likely be able to justify an overpass with fencing and jump-outs (Table 8). There are three MESs that have the highest costs in the study area and exceed this annual average cost – Yamnuska Bow Valley East Corridor ($48,119), South Canmore-Bow Flats Corridor ($28,991) and Georgetown-Harvie Heights MES ($33,027).

# 9. RECOMMENDATIONS FOR THE TEN MITIGATION EMPHASIS SITES

## 9.1 Mitigation Measures

Although there have been many mitigation measures suggested to reduce WVCs, only a few of the measures have the potential to substantially reduce WVCs (Huijser et al. 2008, Clevenger & Huijser 2011). Only wildlife fencing and animal detection systems have shown to be able to reduce WVCs with large mammals substantially (>80%). It is important to note however, that animal detection systems should still be considered experimental whereas the estimate for the effectiveness of wildlife fencing in combination with wildlife underpasses and overpasses is much more robust. Electrified mats used in place of Texas gates or cattle guards have been shown to be effective in keeping ungulates from accessing highway rights-of-way or entering in fenced areas (Seamans and Helon 2008). The development and testing of "electro-mats" in the next few years will help determine the efficacy of these measures in dealing with problems with animal movement at the ends of fences.

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:

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

As part of the 2007 report, a Technical Working Group was convened which 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, and
3. Measures or practices that are proven ineffective.

Our recommendations for improving motorist safety and wildlife connectivity for the TCH include a total of five different mitigation measures. Table 9 includes a list of most of the measures available today, 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 9: Wildl ife mitigation measures, their focus and effectiveness.**

| Mitigation measure | Effectiveness[1] | Type[2] | Category[3] |
|---|---|---|---|
| Intercept feeding (salt licks) | N/A[4] | Animal | Promising |
| De-icing alternatives | N/A | Animal | Promising |
| Variable message sign | N/A | Driver | Promising |
| Animal detection system | 87% | Driver | Promising |
| Fencing | 86% | Separate | Proven |
| Underpass with waterflow | 86% | Animal | Proven |
| Underpass – wildlife | 86% | Animal | Proven |
| Underpass – multi-use | 86% | Animal | Proven |
| Overpass – wildlife | 86% | Animal | Proven |
| Overpass – multi-use | 86% | Animal | Proven |

[1]Effectiveness: the average percentage reduction in annual wildlife-vehicle collisions after application of the mitigation measure.

[2] Type of mitigation measures include: Driver-Measures that attempt to influence driver behaviour; Animal- Measures that attempt to influence animal behaviour; and Separate-Measures that physically separate animals from the roadway. From Huijser et al. 2007.

[3] Proven: Measures that should be implemented (where appropriate); Promising: Measures that appear promising, but require further investigation. From Huijser et al. 2007.

[4] Not Available: no data on effectiveness.

## 9.2. Recommended Mitigation Measures

As previously mentioned, mitigation emphasis sites are specific locations within the TCH study area where opportunities for reducing WVCs and improving connectivity for all wildlife are highest, including fragmentation-sensitive species. Focusing highway mitigation efforts in these areas should improve motorist safety, reduce wildlife mortalities and improve habitat linkages and animal movement through transitional habitat along these highway segments.

From the field evaluation of the 10 mitigation emphasis sites, recommendations were grouped into actions that can be carried out, from simple landscaping and earth moving work, to more costly installation of fencing or below-grade passage structures. For some of the sites mitigation makes more sense (from a cost and ecological perspective) if combined with a neighbouring MES.

We developed recommendations for mitigation opportunities at each mitigation emphasis site along the TCH. The relative importance of each site varies by species and local landscape attributes across the 39 kilometer TCH study area. Each MES and its conservation ranking (Table 2) was informed by field data on wildlife movement, wildlife mortality, expert opinion, and opportunities and limitations with respect to adjacent land use (see "Prioritizing Mitigation Emphasis Sites", Section 5.2, p. 20). A variety of mitigation measures are recommended; from simple to complex, some requiring minor earthmoving and landscaping, while others necessitate structural work (e.g., fencing, Jersey barrier replacement).

### *9.2.1 Kananaskis River Bridge*

The area has high WVC rates, is of high local and regional conservation significance, and excellent options for mitigating the effects of the TCH. Land use security is relatively high, but mitigation alternatives should continue to focus on managing adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH. Given the local conservation value, it will be critical to maintain vegetative cover and riparian habitat along the Kananaskis River. Wildlife passage appears possible and likely to be occurring within the span bridge on the West side of the river.

Recommendations to reduce WVCs and improve wildlife passage in the area include:

(1) On East side of river, do earthwork underneath and adjacent to span bridge that will better adapt the area for wildlife movement. Earthwork would consist of removing fill in some areas and landscape a more suitable wildlife path under the bridge span. Landscaping and vegetating the immediate area conducive to wildlife use (cover) will be needed.

(2) In addition to (1), install 2.4 m high wing-fencing, particularly on the East side of bridge to funnel movement of wildlife to bridge. Install *animal-detection system* (with motorist warning signage) at fence end and/or boulder field to minimize animal intrusions to the right-of-way. Jump-outs or escape ramps should be located appropriately to allow animals to escape the right-of-way should they gain access.

### *9.2.2 Yamnuska Bow Valley East Corridor*

Mitigation alternatives should focus on reducing WVCs in this highly problematic area, the highest rate of WVC in the entire study area. The site has high local and regional conservation significance and highway mortality but transportation mitigation options are few. It will be difficult to install below-grade passage at this site, therefore above-grade mitigation is required.

Recommendations to reduce collisions and improve wildlife passage in the area include:

(1) Install *animal-detection systems* with or without fencing to warn motorists of wildlife on or near the TCH. Fenced systems will have *animal-detection system* and/or boulder fields at fence ends to minimize animal intrusions into the right-of-way. Jump-outs should be located appropriately to allow animals to escape the right-of-way should they gain access.

(2) Fence entire section encompassing this MES with Kananaskis River Bridge MES to the east. *Electro-mats* would be situated where fence crosses the Hwy 1X/Seebe interchange roads (n=4 sites). *Animal-detection system* and/or boulder fields should be placed at east and west fence ends and associated jump-outs located within the fenced area to allow animal escape.

### *9.2.3. Yamnuska Bow Valley Central Corridor*

Mitigation alternatives should focus on reducing WVCs in this problematic area. Recommendations to reduce collisions and improve wildlife passage in the area include the same as for site 2: Yamnuska-Bow Valley East Corridor MES to the east. Difficult to install below-grade passage at this site, therefore above-grade mitigation is required.

This site could be part of sectional mitigation scheme, with continuous fencing encompassing this MES with the Yamnuska Bow Valley East Corridor). *Animal-detection system* and/or boulder fields would be situated at east and west fence ends and associated jump-outs located within the fenced area to allow animal escape.

### *9.2.4. Yamnuska Bow Valley West Corridor*

Not an area of high regional conservation significance or highway mortality. Nonetheless, mitigation alternatives should focus primarily on reducing WVCs in this area. This site would easily accommodate a below-grade passage structure (*underpass*) given the amount of fill and raised highway profile.

Mitigation would create highest value at site if part of a sectional mitigation scheme that mitigates more than the specific site, but a larger stretch of TCH to the east and includes fencing and *animal-detection systems* at ends of fences.

### *9.2.5. Yamnuska-Lac des Arcs Corridor*

This is an area of high regional conservation significance for carnivores and wildlife mortality. Mitigation alternatives should focus on continuing to manage adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH. Mitigation should focus primarily on reducing WVCs in this area. This site can accommodate a below-grade passage structure (underpass) given the raised highway profile, particularly on the North side. There is a drainage culvert in place that could be retrofitted as an underpass.

This site is best suitable as a stand-alone, site-specific mitigation or combined with the Heart Creek MES (see below). Recommended dimension for w*ildlife underpass* is minimum 2.2 m high x 3 m wide, e.g., prefabricated concrete box culvert. Wing *fencing* (ca. $\geq$200 m) should be used with *animal detection system* at fence ends or boulder field with nearby jump-outs.

### *9.2.6. Heart Creek*

An area of relatively low local and regional conservation significance for wildlife, but with elevated wildlife mortality rates in area. Mitigation alternatives should focus on managing the adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH. The hamlet of Lac des Arcs on north side likely deflects most wildlife movement around the community. Mitigation should focus primarily on reducing WVCs in this area and ensuring greater movement of wildlife through the existing Heart Creek bridge structure. Most wildlife in area are likely able to pass below-grade using the creek underpass.

This site is best suitable as a stand-alone, site-specific mitigation measure or combined with the Yamnuska-Lac des Arcs Corridor MES (see above). Fencing could tie the two MES together, funneling animal movement to a concrete box culvert and the Heart Creek underpass, respectively. Wing *fencing* (ca. $\geq$200 m) should be used with *animal detection system* at fence ends or boulder field with nearby jump-outs.

### *9.2.7 Bow River Bridge*

This is an area of relatively low highway mortality, but high local conservation significance for wildlife. Mitigation alternatives therefore should focus on (1) managing the adjacent lands (near Town of Canmore) south of the highway in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH and (2) reducing WVCs on the TCH. WVC reduction measures should be part of a combined strategy with the South Canmore-Bow Flats Corridor MES, given their proximity and similar highway impact issues. Combining mitigation work at both MES and linking it to the Stewart Creek-Dead Man's Flats section will have an important mitigation effect on WVCs and wildlife movement in a critical part of the Bow Valley corridor.

There is travel space on the East side of the Bow River Bridge. Adapting the West side of the bridge for wildlife passage should be part of a combined MES strategy (see below). Fencing continues as part of the South Canmore-Bow Flats Corridor.

### *9.2.8 South Canmore-Bow Flats Corridor*

This site is closely associated with the Bow River Bridge MES (above) and therefore any mitigation should be planned for both sites. The site has a relatively high local and regional conservation value and is an area of high WVCs.

Lands on either side are protected by the Canmore Nordic Centre Provincial Park and Bow Valley Provincial Park but this site is close to the Town of Canmore and wildlife movement has the potential to be threatened by development. It will therefore be critical to ensure the preservation of the adjacent wildlife corridor and other natural habitats that move wildlife near the TCH. Mitigation alternatives therefore should focus on (1) strict management of the adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH and (2) reducing WVCs on the TCH.

Recommendations to reduce collisions and improve wildlife passage at this site include one wildlife underpass and fencing that encompasses the two MES. Fencing ties into Bow River Bridge to the east and CPR bridge to the west. Recommended dimension for w*ildlife underpass* is minimum 4 m high x 7 m wide, e.g., corrugated steel elliptical culvert. Boulder fields are not needed since the fence ties into the two bridges.

### *9.2.9 Georgetown Corridor*

The area is of moderate importance for local conservation and can be problematic for WVCs. The transportation mitigation options are few given the location surrounded by highway interchange and residential/commercial development. There are multiple lanes of traffic on the TCH (off/on ramps plus 4 lanes). Recommendations to reduce collisions and improve wildlife passage in the area include replacing Jersey barriers (precast concrete modular barriers) in central median with a *cable barrier system* which would allow easier movement of wildlife across the TCH.

### *9.2.10 Georgetown-Harvie Heights*

This site is second to the Yamnuska Bow Valley East Corridor in terms of high WVC frequency. Local conservation value is high given its proximity to Banff National Park and habitat on periphery of Town of Canmore. Land use security is high as Crown lands are located on both sides of the highway. Like the Georgetown Corridor, there are few mitigation options other than replacing Jersey barriers with cable barriers. There are as many as 8 lanes of traffic (6 lanes on TCH, 2 lanes on Harvie Heights road) on this section of TCH near the park entrance. An existing culvert could be retrofitted for wildlife passage, but would require raising the highway profile 0.5-1.0 m.

## 10. CONCLUSION AND RECOMMENDATIONS

This report identified ten MESs along the TCH within the Bow Valley where focusing highway mitigation efforts should improve motorist safety, reduce wildlife mortalities and improve habitat linkages and animal movement through transitional habitat along these highway segments. MESs were identified from an analysis of WVC datasets provided by the Alberta government as well as a review of grey literature reports on carnivore and ungulate connectivity in the region. It is important to consider ecological connectivity, for both fragment sensitive species and local wildlife populations, during highway mitigation assessments due to the importance of wildlife movement as a strategy to respond to environment and climatic change.

A limitation of the WVC dataset in the Bow Valley is the non-systematic nature of the data collection; observations are based on citizens or government staff opportunistically reporting wildlife mortality along the TCH. Therefore the accuracy of the spatial location and magnitude of the WVC's occurring per km is unknown. It is likely the WVC magnitude, based on a 10 year average of 62 WVC's per annum in the bow Valley, is underestimated. In addition, it is not possible to accurately compare the rate of WVC's occurring along this stretch of the TCH in relation to other highways in Alberta and Canada due to inconsistencies in data collection. This leads to difficultly for Alberta Transportation (AT) and other government agencies to prioritize transportation mitigation from a provincial perspective. We therefore *recommend that the province consider developing a methodology for systematically monitoring the rate of WVC's across the highway network in Alberta to ensure WVC hotspots can be prioritized for transportation mitigation.*

Each MES within the Bow Valley was rated based on five criteria; highway mortality, regional conservation significance, local conservation value, land security and transportation mitigation opportunity, to assist government agencies in prioritizing mitigation along the TCH. The Kananaskis River Bridge, Yamnuska Bow Valley East Corridor and Heart Creek ranked as top priority MESs for transportation mitigation efforts, both these sites occur on the east end of the study area near the junction with Highway 40 and TCH.

At each MES, we suggest mitigation strategies that have been proven effective or show promise of reducing WVCs by 80%. Based on research, traditional wildlife signage and reflectors are not considered as effective mitigation strategies, while underpasses, wildlife fencing and jump-outs are considered effective. Animal detection systems although not proven, have shown promise and are therefore recommended at some of the MESs. A cost benefit analysis of each MES identified 6 out of the 10 sites where UVCs are occurring at a cost of more than $18,000 per year, thereby making it cost effective to build underpasses, fencing and jump-outs. The three MESs that have the highest costs in the study area are Yamnuska Bow Valley East Corridor ($48,119), South Canmore-Bow Flats Corridor ($28,991) and Georgetown-Harvie Heights MES ($33,027) where it is cost effective to build underpass or overpass, fencing and jump-outs. The first two sites, Yamnuska Bow Valley East Corridor and South Canmore-Bow Flats Corridor have desirable ranking scores in the prioritization matrix, while the Georgetown Harvie-Heights MES was rated very low for transportation mitigation opportunities due to location and the width of lanes occurring at this location. *Transportation mitigation at Yamnuska Bow Valley East Corridor and South Canmore-Bow Flats Corridor MESs are cost effective to society and it is our recommendations these MESs be prioritize for mitigation along the TCH.*

*The recommendations for the Yamnuska Bow Valley East Corridor MES are considered in the broader context of the Yamnuska linkage area due to difficulties in establishing below grade underpasses along this stretch of the TCH and the high mortality surrounding the Yamnuska Bow Valley East Corridor East. Therefore four MESs (Kananakis River Bridge, Yamnuska Bow Valley East Corridor, Yamnuska Bow Valley Central Corridor and Yamnuska Bow Valley West Corridor) are included in this broader linkage area. Mitigation recommendations include facilitating wildlife movement at the Kananaskis River Bridge (eastern edge) by removing fill in some areas and landscaping a more suitable wildlife path under the bridge span, fencing to Yamnuska Bow Valley West Corridor (western edge) and then building an underpass at this site where the highway grade is more forgiving. We recommended installing an animal detection system at the fence ends or rocks to deter wildlife movement within the highway right away.*

*The recommendations for the South Canmore-Bow Flats Corridor are considered in the broader context of the Bow Flats Linkage encompassing two MESs, Bow River Bridge and South Canmore-Bow Flats Corridor. Recommendations to reduce collisions and improve wildlife passage within the Bow Flats Linkage include one wildlife underpass and fencing that encompasses the two MES. Fencing ties into Bow River Bridge to the east and CPR bridge to the west. In addition we recommend strict management of the adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH*.

In 2004, the Dead Man's Flats underpass was built using G8 Legacy Funds. It was possible to evaluate the effectiveness and costs savings of the underpass. WVC data was available at the location for six years, both pre- and post-construction. Total WVCs dropped from an annual average of 11.8 pre-construction to a six year annual average of 2.5 WVCs post-mitigation construction. From a cost-to-society perspective, mitigation reduced the annual average cost by over 90%, from an $128,337 average per year to a resulting $17,564 average per year. This 3 km section of the highway within the project area provides local evidence of the effectiveness and cost benefit potential for the ten MESs in this study. *Long term monitoring of WVC's and wildlife movement along the TCH will enable researchers to highlight the benefits of mitigation strategies to local and regional wildlife populations as well as cost savings to society.*

## 11. REFERENCES

Bow Corridor Ecosystem Advisory Group (BCEAG). 1998. Wildlife Corridor and Habitat Patches Guidelines for the Bow Valley. 27pp.

Clevenger, A.P. & Waltho, N. 2000 Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology, 14, 47-56.

Clevenger, A.P., B. Chruszcz & K. Gunson. 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. Wildlife Society Bulletin 29: 646–653.

Clevenger, A.P. & N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121:453-464.

Clevenger, A.P., Long, R. and R. Ament. 2008. I-90 Snoqualmie Pass East Wildlife Monitoring Plan. Prepared for the Washington Department of Transportation, Yakima, Washington. 47 pp.

Clevenger, T. & M.P. Huijser. 2011. Handbook for Design and Evaluation of Wildlife Crossing Structures in North America. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.westerntransportationinstitute.org/documents/reports/425259_Final_Report.pdf

Crooks, K.R. and Sanjayan, M. 2006. Connectivity conservation. Cambridge University Press, Cambridge, UK.

da Fonseca, G. A. B., W. Sechrest, and J. Ogelthorpe. 2005. Managing the matrix. Pages 346–358 in T. E. Lovejoy and L. Hannah, editors. Climate change and biodiversity. Yale University Press, New Haven, Connecticut.

Epps, C.W., P.J. Palsbøll, J.D. Weyhausen, G.K. Roderick, R.R. Ramey, D.R. McCullough. 2005. Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters 8: 1029-1038.

Fahrig, L., J.H. Pedlar, S.E.Pope, P.D. Taylor, and J.F. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation 74:177-182.

Ford, AT, AP Clevenger, K Rettie. 2010. Banff Wildlife Crossings, TransCanada Highway, Alberta – An international public-private partnership. Pages 157-172 in *Safe passages: highways, wildlife and habitat connectivity*. J Beckmann, AP Clevenger, M Huijser, J Hilty (eds.). Island Press, Washington DC

Forman, R.T.T., L. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-31.

Gerlach, G., K. Musolf. 2000. Fragmentation of landscape as a cause for genetic subdivision in bank voles. Conservation Biology 14:1066-1074.

Gibbs, J.P., D.A. Steen. 2005. Trends in Sex Ratios of Turtles in the United States: Implications of Road Mortality. Conservation Biology 19: 552–556.

Gibbs, J.P., G.Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647-1652.

Gilbert-Norton, L., Wilson, R., Stevens, J.R. and Beard, K.H. 2010. A meta-analytic review of corridor effectiveness. Conservation Biology, 24 (3), 660–668.

Golder Associates. 2002. Final Report: Assessment of Wildlife Corridors within in DC site 1, DC site 3, and District R. Prepared for Three Sisters Resort Inc. and Town of Canmore.

Gunther, K.A., Biel, M.J. and H.L. Robinson. 2000. Influence of vehicle speed and vegetation cover-type on road-killed wildlife in Yellowstone National Park. In: Messmer TA, West B, editors. Wildlife and highways: seeking solutions to an ecological and socio-economic dilemma. 2000 September 12-16: Nashville, TN. 169pp.

Heller, N.E. and E.S. Zavelata. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biological Conservation, 142(2009), 14-32.Heuer K. and T.

Lee 2010. Private Land Conservation Opportunities in the Bow Valley. Prepared for the Yellowstone to Yukon Conservation Initiative, the Bow valley Land Conservnacy and the Nature Conservancy of Canada. Calgary, AB.

Hilty, J., W. Lidicker, and A. Merenlender. 2006. Corridor ecology: the science and practice of linking landscapes for biodiversity conservation. Island Press, Washington, DC.

Huijser, M.P., P.T. McGowen, W. Camel, A. Hardy, P. Wright, A.P. Clevenger, L. Salsman & T. Wilson. 2006. Animal vehicle crash mitigation using advanced technology. Phase I: review, design and implementation. SPR 3(076). FHWA-OR-TPF-07-01, Western Transportation Institute – Montana State University, Bozeman, Montana, USA.

Huijser, M.P., J. Fuller, M.E. Wagner, A. Hardy & A.P. Clevenger. 2007a. Animal–vehicle collision data collection. A synthesis of highway practice. NCHRP Synthesis 370. Project 20-05/Topic 37-12. Transportation Research Board of the National Academies, Washington, D.C., USA.

Huijser, M.P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith & R. Ament. 2008. Wildlife-vehicle collision reduction study. Report to Congress. U.S. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.tfhrc.gov/safety/pubs/08034/index.htm

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament & P.T. McGowen. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. Ecology and Society 14(2): 15. [online] URL: http://www.ecologyandsociety.org/viewissue.php?sf=41

Lee, T., Managh, S. and N. Darlow. 2010. Spatial-temporal patterns of wildlife distribution and movement in Canmore's benchland corridor. Prepared for Alberta Tourism, Parks and Recreation, Canmore, Alberta.

Lovallo, M.J., E.M. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24 71-76.

Mawdsley, J.R., O'Malley, R., Ojima, D.S. 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology, 23 (5), 1080–1089.

McGuire, T.M. and Morrall, J.F. 2000. Strategic highway improvements to minimize environmental impacts within the Canadian Rocky Mountain national parks. Canadian Journal of Civil Engineering 27, 523-32

Mumme, R.L., S.J. Schoech, G.E. Woolfenden, J.W. Fitzpatrick. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. Conservation Biology, 14:501-12.

Noss, R.F., H.B. Quigley, M.G. Hornocker, T. Merrill, P.C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology 10:949-963.

Percy, M. 2003. Temporal and spatial activity patterns of large carnivores in the Bow Valley of Banff National Park. M.Sc. thesis. University of Alberta. Edmonton, Alberta.

Ritters, K.H. and J.D. Wickham. 2003. How far to the nearest road? Frontiers in Ecology and Environment 1:125-129. Sawaya, M. 2012. Using noninvasive genetic sampling methods to estimate demographic and genetic parameters for large carnivore populations in the Rocky Mountains. PhD thesis, Montana State University, Bozeman, Montana USA.

Seamans, T., D. Helon. 2008. Comparison of electrified mats and cattle guards to control white-tailed deer access through fences. USDA National Wildlife Research Center, Staff Publications. Paper 798.

Seiler, A. 2003. The toll of the automobile: Wildlife and roads in Sweden. Doctoral dissertation. Swedish University of Agricultural Sciences.

Sweanor, L.L., K.A. Logan, M.G. Hornocker. 2000: Cougar dispersal patterns, metapopulation dynamics, and conservation. Conservation Biology 14:798-808.

Waller, J., C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management, 69:985-1000.

Whittington, J. and A. Forshner. 2009. An Analysis of wildlife snow tracking, winter transect, and highway underpass data in the Eastern Bow Valley.

Wolf, P. 1981. Land in America: its value, use and control. New York: Pantheon Books.

## 12. APPENDIX A: WILDLIFE VEHICLE COLLISION DATA CLEAN UP

Process for pulling out road kill data for TCH WVC data from 2006-2010, acquired from the AESRD ENFOR database.

1. Sorted database on Cause of Death Field: Highways – removed records into new spreadsheet
2. Reviewed Cause of Death “pending” records and pulled TCH road kill possibilities into new spreadsheet
3. Sorted Highways on Occurrence Types: found the following:
    a. Wildlife dead
    b. Wildlife complaint road kill injured
    c. WC: Sightings
    d. WC: Injured
    e. No occurrence type – reviewed record notes for road kill.
4. Resulted in 372 records from 2006-2010 (5 years)
5. Sorted by location and removed records without a location (unknown), 77 records, of which 22 were for the TCH (the unknown location records were included in total annual rate calculations for TCH)
6. Removed WMU, descriptive fields, separate date into month and year, removed occnum
7. Cleaned titles (removed hyphens and shortened)
8. Saved as CVS file to import into GIS, displayed using easting and northing
9. Extracted TCH records (total 350), cleaned by:
    a. Selected only records on TCH from Banff Park Gate to Hwy 40
    b. Cleaned TCH record locations by buffering TCH by 1km and removing records beyond this buffer, 5 records were outside of buffer and were counted as location unknown as they were identified as road kill.
    c. Reviewed other records within buffer but with different highway label, added 16 records (labeled as Canmore, Harvey Heights, Hwy 40 , but attributed as road-kill from Hwy and located within 1km buffer of Hwy)
10. Resulting in 344 location known records of road kills associated with the TCH from 2006-2010

11. Snapped remaining records to TCH
12. Export from ARCGIS to excel
13. In excel calculated the number of mortality records per year and average rate over the five year period. Pulled out rate for each species on known locations.
14. For average annual wildlife mortality add in the unknown location records, these were identified as being associated with TCH but did not include enough detail to be added into spatial file.

1997 to 2005- Acquired from Scott Jevons cleaned database

1. Important WVC mortality data into GIS
2. Selected TCH records, removed 8 records to the east of Hwy 40 or any records over 1km away from the TCH
3. There are 570 records, 65 with an unknown location, leaving 505 for a spatial analysis where locations were needed.
4. Removed 1997 data – 27 records and one record from 1993.
5. There were 481 records used in spatial analysis from 1998-2010.

Merging datasets 1998-2010

1. Snapped both datasets to Highway 1 – converted to one line.
2. Segmented into 1 km sections from Banff park gate to Hwy 40.
3. Merged datasets from 1998-2010, cleaned names species for consistency.
4. Enumerated the data per species per 1 km segment and exported data.  Deer, Elk, Moose, BHS, Other.

# 13. APPENDIX B: MITIGATION EMPHASIS SITE SUMMARIES

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. These Summary Information Sheets are a quick and easy reference that summarizes mitigation opportunities at each MES.

| 1_Kananaskis River Bridge Summary | |
|---|---|
| Description | |
| **Location:** UTM: 636223, 5661201 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 5 | |
| Local conservation value: 4 | |
| Regional conservation significance: 4 | |
| Land use security: 4 | |
| Transportation mitigation opportunities: 5 | |
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk.<br>• Provide safe movement for all wildlife species across highway, primarily deer, elk and bears. | |
| Existing infrastructure | |
| • Large span bridge over the Kananaskis River. | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species.<br>**Regional conservation and connectivity**: Common species primarily, some grizzly bear movements across highway may occur. | |
| Land use security | |
| Score: 4 | |
| **Current land use**: Land to the east of the MES is private, land to the west is under crown jurisdiction. | |
| Transportation mitigation opportunities | |

| Score: 5 | |
|---|---|
| The area has high WVC rates, is of high local and regional conservation significance, and excellent options for mitigating the effects of the TCH. Land use security is relatively high, but mitigation alternatives should continue to focus on managing adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH. Given the local conservation value, it will be critical to maintain vegetative cover and riparian habitat along the Kananaskis River. Wildlife passage appears possible and likely to be occurring within the span bridge on the West side of the river.<br>Recommendations to reduce WVCs and improve wildlife passage in the area include:<br>(1) On East side of river, do earthwork underneath and adjacent to span bridge that will better adapt the area for wildlife movement. Earthwork would consist of removing fill in some areas and landscape a more suitable wildlife path under the bridge span. Landscaping and vegetating the immediate area conducive to wildlife use (cover) will be needed.<br>(2) In addition to (1), install 2.4 m high wing-fencing, particularly on the East side of bridge to funnel movement of wildlife to bridge. Install *animal-detection system* (with motorist warning signage) at fence end and/or boulder field to minimize animal intrusions to the right-of-way. Jumpouts or escape ramps should be located appropriately to allow animals to escape the right-of-way should they gain access. | |

| 2_Yamnuska Bow Valley East Corridor Summary | |
|---|---|
| Description | |
| **Location:** UTM: 635770, 5660280 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 5 | |
| Local conservation value: 5 | |
| Regional conservation significance: 5 | |
| Land use security: 5 | |
| Transportation mitigation opportunities: 2 | |

| | |
|---|---|
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk.<br>• Provide safe movement for all wildlife species across highway, primarily deer, elk and bears. | |
| Existing infrastructure | |
| • None. | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species.<br>**Regional conservation and connectivity**: Common species primarily, some black bear and cougar movements across highway may occur. | |
| Land use security | |
| Score: 5 | |
| **Current land use**: Land on both sides of highway is under provincial crown jurisdiction. | |
| Transportation mitigation opportunities | |
| Score:  2 | |
| Mitigation alternatives should focus on reducing WVCs in this highly problematic area, the highest rate of WVC in the entire study area. The site is has high local and regional conservation significance and highway mortality Transportation mitigation options are few. It will be difficult to install below-grade passage at this site, therefore above-grade mitigation is required.<br>Recommendations to reduce collisions and improve wildlife passage in the area include:<br>(1) Install *animal-detection systems* with our without fencing to warn motorists of wildlife on or near the TCH. Fenced systems will have *animal-detection system* and/or boulder fields at fence ends to minimize animal intrusions into the right-of-way. Jump-outs should be located appropriately to allow animals to escape the right-of-way should they | |

| | |
|---|---|
| gain access.<br>(2) Fence entire section encompassing this MES with Kananaskis River Bridge MES to the east. *Electro-mats* would be situated where fence crosses the Hwy 1X/Seebe interchange roads (n=4 sites). *Animal-detection system* and/or boulder fields should be placed at east and west fence ends and associated jumpouts located within the fenced area to allow animal escape. | |

| | |
|---|---|
| 3_ Yamnuska Bow Valley Centre Corridor Summary | |
| Description | |
| **Location:** UTM: 634400, 5659203 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 3 | |
| Local conservation value: 5 | |
| Regional conservation significance: 5 | |
| Land use security: 5 | |
| Transportation mitigation opportunities: 2 | |
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk.<br>• Provide safe movement for all wildlife species across highway, primarily deer, elk and bears. | |
| Existing infrastructure | |
| • None. | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species.<br>**Regional conservation and connectivity**: Common species primarily, some black bear and cougar movements across highway may occur. | |
| Land use security | |
| Score: 5 | |
| **Current land use**: Land on both sides of highway is under provincial crown jurisdiction. | |
| Transportation mitigation opportunities | |

| Score: 2 | |
|---|---|
| Mitigation alternatives should focus on reducing WVCs in this problematic area. Recommendations to reduce collisions and improve wildlife passage in the area include the same as for site 2: Yamnuska-Bow Valley East Corridor MES to the east. Difficult to install below-grade passage at this site, therefore above-grade mitigation is required.<br><br>This site could be part of sectional mitigation scheme, with continuous fencing encompassing this MES with the Yamnuska Bow Valley East Corridor). *Animal-detection system* and/or boulder fields would be situated at east and west fence ends and associated jumpouts located within the fenced area to allow animal escape. | |

| | |
|---|---|
| 4_ Yamnuska Bow Valley West Corridor Summary | |
| Description | |
| **Location:** UTM: 632365, 5659234 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 3 | |
| Local conservation value: 4 | |
| Regional conservation significance: 2 | |
| Land use security: 5 | |
| Transportation mitigation opportunities: 4 | |
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk.<br>• Provide safe movement for all wildlife species across highway, primarily deer, elk and bears. | |
| Existing infrastructure | |
| • None | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species.<br>**Regional conservation and connectivity**: Common species primarily, some black bear and cougar movements across highway may occur. | |
| Land use security | |
| Score: 5 | |
| **Current land use**: Land on both sides of highway is under provincial crown jurisdiction. | |
| Transportation mitigation opportunities | |

| Score: 4 | |
|---|---|
| Not an area of high regional conservation significance or highway mortality. Nonetheless, mitigation alternatives should focus primarily on reducing WVCs in this area. This site would easily accommodate a below-grade passage structure (underpass) given the amount of fill and raised highway profile.<br><br>Mitigation would create highest value at site if part of a sectional mitigation scheme that mitigates more than the specific site, but a larger stretch of TCH to the east and includes *fencing* and *animal-detection systems* at ends of fences. At least one *jump-out* (escape ramp) should be installed on each side of highway to allow wildlife to escape fenced area. | |

| | |
|---|---|
| 5_ Yamnuska Lac des Arcs Corridor Summary | |
| Description | |
| **Location:** UTM: 630512, 5658227 | |
| **Species:** Carnivores | |
| Wildlife–vehicle collisions: 4 | |
| Local conservation value: 3 | |
| Regional conservation significance: 5 | |
| Land use security: 5 | |
| Transportation mitigation opportunities: 4 | |
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk, but also bears and other carnivores.<br>• Provide safe movement for all wildlife species across highway, primarily carnivore and ungulate species. | |
| Existing infrastructure | |
| • None | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species, predominantly deer.<br>**Regional conservation and connectivity**: Common species are a priority, however area is believed to be corridor for movement of grizzly bears and other carnivores. | |
| Land use security | |
| Score: 5 | |
| **Current land use**: Land on both sides of highway is under provincial crown jurisdiction. | |

| Transportation mitigation opportunities | |
|---|---|
| Score: 4 | |
| An area of high regional conservation significance for carnivores and wildlife mortality in general. Mitigation alternatives should focus on continuing to manage adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH. Mitigation should focus primarily on reducing WVCs in this area. This site can accommodate a below-grade passage structure (*underpass*) given the raised highway profile, particularly on the North side. There is a drainage culvert in place that could be retrofitted as a *wildlife underpass*.<br><br>This site is best suitable as a stand-alone, site-specific mitigation or combined with the Heart Creek MES (see below). Recommended dimension for *wildlife underpass* is minimum 2.2 m high x 3 m wide, e.g., prefabricated concrete box culvert. *Wing fencing* (ca. $\geq$200 m) should be used with *animal detection system* and'or boulder field at fence ends. At least one *jump-out* (escape ramp) should be installed on each side of highway to allow wildlife to escape fenced area. | |

| 6_ Heart Creek Summary | |
|---|---|
| Description | |
| **Location:** UTM: 629212, 5657152 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 4 | |
| Local conservation value: 2 | |
| Regional conservation significance: 3 | |
| Land use security: 2 | |
| Transportation mitigation opportunities: 5 | |
| Wildlife objectives | |
| • Provide safe movement for all wildlife species under TCH and through bridge.<br>• Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk. | |
| Existing infrastructure | |
| • 1.8 m high x 8 m wide concrete box bridge structure for Heart Creek flow. | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species.<br>**Regional conservation and connectivity**: Common species primarily, some black bear and cougar movements across highway may occur. | |
| Land use security | |
| Score: 2 | |
| **Current land use**: Land to the north is private and land to the south is under provincial crown jurisdiction. | |

| Transportation mitigation opportunities | |
|---|---|
| Score: 5 | |
| An area of relatively low local and regional conservation significance for wildlife, but with elevated wildlife mortality rates in area. Mitigation alternatives should focus on managing the adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH. The hamlet of Lac des Arcs on north side likely deflects most wildlife movement around the community. Mitigation should focus primarily on reducing WVCs in this area and ensuring greater movement of wildlife through the existing Heart Creek bridge structure. Most wildlife in area are likely able to pass below-grade using the creek underpass.<br>This site is best suitable as a stand-alone, site-specific mitigation measure or combined with the Yamnuska-Lac des Arcs Corridor MES (see above). *Fencing* could tie the two MES together, funneling animal movement to a concrete box culvert and the Heart Creek underpass, respectively. *Wing fencing* (ca. ≥200 m) should be used with *animal detection system* and/or boulder field at fence ends. At least one *jump-out* (escape ramp) should be installed on each side of highway to allow wildlife to escape fenced area. | |

| 7_ Bow River Bridge Summary | |
|---|---|
| Description | |
| **Location:** UTM: 617529, 5658112 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 2 | |
| Local conservation value: 5 | |
| Regional conservation significance: 3 | |
| Land use security: 4 | |
| Transportation mitigation opportunities: 5 | |
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk, but also wolves, bears and other carnivores.<br>• Provide safe movement for all wildlife species across highway, primarily carnivore and ungulate species. | |
| Existing infrastructure | |
| • Open-span bridge over Bow River. | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species, but primarily deer, elk, wolves and bears.<br>**Regional conservation and connectivity**: Common species primarily, some black bear, wolf and cougar movements across highway may occur. | |
| Land use security | |
| Score: 4 | |
| **Current land use**: Land to the East of the MES is private, land to the West | |

| | |
|---|---|
| is under crown jurisdiction. | |
| Transportation mitigation opportunities | |
| Score: 5 | |
| This is an area of relatively low highway mortality, but high local conservation significance for wildlife. Mitigation alternatives therefore should focus on (1) managing the adjacent lands (near Town of Canmore) south of the highway in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH and (2) reducing WVCs on the TCH. WVC reduction measures should be part of a combined strategy with the South Canmore-Bow Flats Corridor MES, given their proximity and similar highway impact issues. Combining mitigation work at both MES and linking it to the Stewart Creek-Dead Man's Flats section will have an important mitigation effect on WVCs and wildlife movement in a critical part of the Bow Valley corridor.<br><br>There is travel space on the East side of the Bow River Bridge. Adapting the West side of the bridge for wildlife passage should be part of a combined MES strategy (see below). *Fencing* continues as part of the South Canmore-Bow Flats Corridor. | |

| 8_ South Canmore – Bow Flats Corridor Summary | |
|---|---|
| Description | |
| **Location:** UTM: 617241, 5658787 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 4 | |
| Local conservation value: 5 | |
| Regional conservation significance: 3 | |
| Land use security: 4 | |
| Transportation mitigation opportunities: 4 | |
| Wildlife objectives | |
| • Reduce current high levels of wildlife–vehicle collisions in this section of highway, primarily deer and elk, but also wolves, bears and other carnivores.<br>• Provide safe movement for all wildlife species across highway, primarily carnivore and ungulate species. | |
| Existing infrastructure | |
| • None | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species, but primarily deer, elk, wolves and bears.<br>**Regional conservation and connectivity**: Common species primarily, some black bear, wolf and cougar movements across highway may occur. | |
| Land use security | |
| Score: 4 | |
| **Current land use**: Land on both sides is under crown jurisdiction. | |

| Transportation mitigation opportunities | |
|---|---|
| Score: 4 | |
| This site is closely associated with the Bow River Bridge MES (above) and therefore any mitigation should be planned for both sites. The site has a relatively high local and regional conservation value and is an area of high WVCs.<br><br>Lands on either side are protected by the Canmore Nordic Centre Provincial Park and Bow valley Provincial Park, but this site is close to the Town of Canmore and wildlife movement has the potential to be threatened by development. It will therefore be critical to ensure the preservation of the adjacent wildlife corridor and other natural habitats that move wildlife near the TCH. Mitigation alternatives therefore should focus on (1) strict management of the adjacent lands in a way that ensures regional wildlife habitat conservation and population connectivity across the TCH and (2) reducing WVCs on the TCH.<br><br>Recommendations are to reduce collisions and improve wildlife passage in the area includes one *wildlife underpass* and fencing that encompasses the two MES. Fencing ties into Bow River Bridge to the east and CPR bridge to the west. Recommended dimension for w*ildlife underpass* is minimum 4 m high x 7 m wide, e.g., corrugated steel elliptical culvert. Boulder fields are not needed since the fence ties into the two bridges. At least one *jump-out* (escape ramp) should be installed on each side of highway to allow wildlife to escape fenced area. | |

| 9_ Georgetown Corridor Summary | |
|---|---|
| Description | |
| **Location:** UTM: 613508, 5664256 | |
| **Species:** Ungulates | |
| Wildlife–vehicle collisions: 4 | |
| Local conservation value: 3 | |
| Regional conservation significance: 3 | |
| Land use security: 4 | |
| Transportation mitigation opportunities: 1 | |
| Wildlife objectives | |
| • Reduce wildlife–vehicle collisions in this section of highway. | |
| Existing infrastructure | |
| • None | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species, primarily deer and elk.<br>**Regional conservation and connectivity**: Common species primarily, deer and elk; some black bear and cougar movements across highway may occur. | |
| Land use security | |
| Score: 4 | |
| **Current land use**: Land on both sides of highway is under provincial crown jurisdiction. | |
| Transportation mitigation opportunities | |
| Score: 1 | |

| | |
|---|---|
| The area is of moderate importance for local conservation and can be problematic for WVCs. The transportation mitigation options are few given the location surrounded by highway interchange and residential/commercial development. There are multiple lanes of traffic on the TCH (off/on ramps plus 4 lanes). Recommendations to reduce collisions and improve wildlife passage in the area include replacing Jersey barriers in central median with *guard rail or cable barrier system* which would allow easier movement of wildlife across the TCH. | |

| | |
|---|---|
| 10_ Georgetown – Harvie Heights Summary | |
| Description | |
| **Location:** UTM: 611931, 5665511 | |
| **Species:** Multi-species | |
| Wildlife–vehicle collisions: 5 | |
| Local conservation value: 4 | |
| Regional conservation significance: 3 | |
| Land use security: 5 | |
| Transportation mitigation opportunities: 1 | |
| Wildlife objectives | |
| • Reduce number of wildlife–vehicle collisions in this section of highway. | |
| Existing infrastructure | |
| • 1.2 m high x 1.8 m wide concrete box culvert. | |
| Target species for mitigation planning | |
| **WVC reduction**: Common species, primarily deer and elk.<br>**Regional conservation and connectivity**: Common species primarily, deer and elk; some black bear and cougar movements across highway may occur. | |
| Land use security | |
| Score: 5 | |
| **Current land use**: Land on both sides of highway is under provincial crown jurisdiction. | |
| Transportation mitigation opportunities | |
| Score: 1 | |

| | |
|---|---|
| This site is second to the Yamnuska Bow Valley East Corridor in terms of high WVC frequency. Local conservation value is high given its proximity to Banff National Park and habitat on periphery of Town of Canmore. Land use security is high as Crown lands are located in both sides of highway. Like the Georgetown corridor, there are few mitigation options other than replacing Jersey barriers with *guard rail or cable barriers*. There are as many as 8 lanes of traffic (6 lanes on TCH, 2 lanes on Harvie Heights road) on this section of TCH near the park entrance. An existing culvert could be retrofitted for wildlife passage, but would require raising the highway profile 0.5-1.0 m. | |