Wildlife-Vehicle Collision and Crossing Mitigation Plan for Hwy 93S in Kootenay and Banff National Park and the Roads in and Around Radium Hot Springs

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16. Abstract This manuscript provides a highway mitigation plan aimed at reducing wildlife-vehicle collisions and providing safe crossing opportunities for wildlife along Hwy 93S through Kootenay and Banff National Park (British Columbia and Alberta, Canada) and the roads in and around Radium Hot Springs (Hwy 93S and Hwy 95). This manuscript identifies and prioritizes road sections for potential mitigation measures, provides a mitigation plan aimed at reducing wildlife-vehicle collisions and providing safe wildlife crossing opportunities, and reviews potential funding mechanisms for such mitigation measures.			
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EXECUTIVE SUMMARY

Wildlife-vehicle collisions (WVCs) affect human safety, property and wildlife, and the number of WVCs has substantially increased across much of North America over the last decades. WVCs along Highway 93 South in Kootenay and Banff National Parks are a concern to Parks Canada. This concern of Parks Canada relates to the human safety aspect as well as the conservation of the natural resources of Kootenay and Banff National Park. Highway 93 South is a major two lane highway that extends 106 km from the Trans-Canada Highway in Banff National Park in Alberta to the Columbia Valley at Radium Hot Springs in British Columbia. Kootenay National Park is a relatively long, narrow park with Highway 93 South bisecting its major valley bottoms. Therefore, much of the park is affected by the transportation corridor.

Parks Canada has a management objective to reduce the death of large mammals as a result of collisions with vehicles. Over the last 33 years (1975 through 2007), 1,531 observations of wildlife mortality within 500m of Highway 93S in Kootenay and nearby portions of Banff National Park have been reported. The most frequently recorded species (those over 5% of mortalities by species) involved with WVCs are white-tailed deer (n=557; 36.4%), elk (n=332; 21.7%), mule deer (n=152; 9.9%), and moose (n=117; 7.6%), with over 23 other species each composing less than 5% of the mortalities. Of those other species, relatively rare or sensitive species have been reported as road kill, including grizzly bear, Canada lynx, wolf, and mountain goat.

This manuscript focuses on Highway 93S through Kootenay and Banff National Park, and roads in and around Radium Hot Springs (Hwy 93S east until Park boundary, Hwy 93S until 4 km south of Radium Hot Springs, and Hwy 95 until 4 km north of Radium Hot Springs). Parks Canada included the road sections in and around Radium Hot Springs in the study area because the area surrounding these road sections are a major part of the winter range of the largest and most productive bighorn sheep population in Kootenay National Park. This herd migrates to low elevation habitat outside Kootenay National Park in winter, and is highly susceptible to highway collisions along provincial Highway 93/95 just south of the village of Radium Hot Springs. Here bighorn sheep not only cross hwy 93S as they move between different parts of their winter range, but the sheep also spent substantial time licking road salt in winter. In and around Radium Hot Springs, 84 (93.3 %) road-killed bighorn sheep, 5 (5.6%) road killed mule deer, and 1 (1.1%) road killed elk have been reported (1975 through 2007) and this number has increased over time.

This manuscript identifies and prioritizes road sections for potential mitigation measures, provides a mitigation plan aimed at reducing wildlife-vehicle collisions and providing safe wildlife crossing opportunities, and reviews potential funding mechanisms for such mitigation measures. The identification and prioritization of the road sections that may require mitigation were based on the assumption that search and reporting effort for road killed animals and animals seen alive on or near the road was similar for all road sections.

The researchers used wildlife road mortality data provided by Parks Canada to identify road sections that may require mitigation to reduce wildlife-vehicle collisions. Wildlife fencing and wildlife underpasses and overpasses are among the most effective mitigation measures and form an important part of this highway mitigation plan (see the literature review prepared for this project: Huijser & Paul 2008). Because of the relatively long life span of these mitigation measures (fences 25 years; underpasses and overpasses 75 years), the identification of road

sections that may require mitigation should reflect the dynamics of the ecosystem over a similar period. Such dynamics include large scale habitat changes as a result of natural succession, fire, and associated changes in the population size and distribution of species of interest.

The researchers based the identification of road sections that may require mitigation on road mortality data from 1975 through 2007; a data set spanning 33 years. The researchers recognize that even though this is a relatively long time period, the data may not reflect all the potential changes in the location and number of wildlife-vehicle collisions, nor the species involved, over the life span of some of the mitigation measures. Nonetheless, the risk of investing in mitigation measures at the wrong location, or designing them for the wrong species, is substantially reduced by using data that cover a relatively long time period.

The researchers recognize that not all of the funds required to implement the suggested mitigation measures may be available on short term. Therefore road sections that may require mitigation were prioritized. The prioritization of the road sections was based on wildlife road mortality data covering a much shorter time period, ten years (1998 through 2007), than the data used to identify these road sections (1975 through 2007). This means that the available funds are first invested at locations that have shown the most road mortality in recent years, and where relatively high and immediate returns on the investments are most likely. At the same time, the risk of investing in a site that may not be a substantial problem over a long time period is minimized because the identification of these road sections is based on a relatively long time period.

The road sections in Kootenay and Banff National Park were analyzed separately from the road sections in and around Radium Hot Springs, because of likely differences in search and reporting effort, differences in funding and implementation procedures for mitigation measures, a focus on bighorn sheep with the data collection program in and around Radium Hot Springs, and the interest of Parks Canada to reduce road mortality for bighorn sheep in and around Radium Hot Springs. The research team only used data related to bighorn sheep for the roads in and around Radium Hot Springs.

Wildlife fencing is among the most effective mitigation measures to reduce wildlife-vehicle collisions and forms an important part of this highway mitigation plan. However, wildlife fencing alone increases the barrier effect and should typically be combined with safe crossing opportunities for wildlife. Such crossing opportunities may consist of wildlife underpasses or overpasses, or at grade crossing opportunities, with or without additional measures such as permanent warning signs or animal detection systems.

The location of potential safe crossing opportunities was based on both mortality data along the road (including road mortality, but not restricted to road mortality) (1975 through 2007) and incidental observations of animals seen alive on or near the road (1975 through 2007). The incidental observations were supplemented with survey data from Parks Canada for the Kootenay Valley, other studies and data obtained through interviewing personnel from Parks Canada. The combined mortality and incidental observation data showed where most wildlife has been observed on or close to the road (1975 through 2007), regardless of whether the individuals were dead or alive. Using both mortality and incidental observations of wildlife seen alive reduces the risk of providing safe crossing opportunities at the wrong locations, as wildlife road kill road sections are not necessarily the same locations where wildlife cross the road most frequently.

The length of the mitigation zones in Kootenay and Banff National Park was 60.3% of the total road length while 79.7% of all reported road mortalities fell within these mitigation zones. The length of the mitigation zones in and around Radium Hot Springs was 37.4% of the total road length while 83.1% of all reported bighorn sheep road mortalities fell within these mitigation zones.

The research team provided cost estimates for the mitigation measures. The proposed mitigation measures in Kootenay and Banff National Park are estimated at Can$20,920,000 (indicative cost estimate, wildlife fencing and crossing opportunities for large mammals only). The proposed mitigation measures in and around Radium Hot Springs are estimated at Can$2,440,000 (indicative cost estimate, wildlife fencing and crossing opportunities for large mammals only). About half of the costs of the mitigation measures were based on wildlife fencing, and the other half were based on safe crossing opportunities for wildlife.

The research team formulated options and potential strategies for alternative configurations of mitigation measures, especially those that may lead to a reduction in cost for the mitigation measures. The main strategies include implementing the mitigation measures on shorter sections, increasing the distance between safe crossing opportunities, and alternative types and smaller dimensions of the safe crossing opportunities. With regard to shorter sections of wildlife fencing, especially in the Kootenay Valley, the research team would like to stress that this may lead to a shift in the location of wildlife-vehicle collisions rather than a reduction in wildlife vehicle collisions. This applies especially to white-tailed deer and elk, species thought to be highly dependent on the grass-herb vegetation in the right-of-way. On the other hand, fencing out the right-of-way along long road sections in the Kootenay Valley may cause white-tailed deer to be displaced, or may cause a strong reduction in their number.

The research team provided a package of tools and data that allows the users of this report to compile alternative configurations of mitigation measures. These tools and data include ranking values for road mortality clusters that allow for the prioritization or selection of the road sections where mitigation measures may be most needed, a breakdown of the species involved with wildlife-vehicle collisions in each mortality cluster, species specific wildlife observation data for the mitigation zones, ranking values for wildlife observation clusters that allow for the prioritization or selection of road sections where safe crossing opportunities may be most needed, a breakdown of the species observed in each wildlife observation cluster, a rationale for the maximum distance between safe crossing opportunities based on the diameter of the home range of the species of interest, and indicative cost estimates for the recommended mitigation measures. These data are presented in the text (primarily as tables) as well as in the appendixes.

The research team suggested where to start with the mitigation measures; south of Kootenay Crossing in Kootenay National Park, and on Mile Hill just south of Radium Hot Springs. For both locations, the research team described various options, including indicative budgets. The mitigation measures south of Kootenay Crossing can be phased. For option 1, wildlife fencing with animal detection systems, phases typically require Can$232,000 alternated with phases that typically require Can$35,000. For option 2, wildlife fencing with large mammal underpasses, phases typically require Can$230,000 alternated with phases that typically require Can$250,000. The work can be stopped or delayed after each phase until sufficient funds available for the next phase.

Finally, the research team provided recommendations for future data collection and an overview of potential funding mechanisms and partnerships for the implementation of the mitigation measures.

The proposed mitigation measures are likely to reduce wildlife-vehicle collisions on the mitigated road sections by about 87%, at least for large mammal species. In addition; the proposed safe crossing opportunities are expected to result in a highway permeability that is meaningful for the individuals that live in the areas adjacent to the highway. However, the research team would like to emphasize that the proposed mitigation measures do not necessarily guarantee viable populations for the selected species or species that are not present in the immediate vicinity of the highway. Road mortality will still occur, especially in the unmitigated road sections, and the level of habitat connectivity provided through the safe crossing opportunities may or may not be sufficient to maintain viable populations on the long term. The research team would like to emphasize that, should there be substantial concerns with regard to the costs for mitigation measures and whether the safe crossing opportunities that would be provided offer sufficient habitat connectivity, there remains the option to not implement the mitigation measures and accept current, and increasing, levels of road mortality and the current, and most likely increasing, barrier effect of highway 93S.

While the costs for the proposed mitigation measures are high, the mitigation measures also reduce costs to society by reducing wildlife-vehicle collisions by an estimated 87% in the mitigation zones. For the road sections in Kootenay National Park, the proposed mitigation measures would have to prevent about 53 collisions with large animals per year to break even. The reported number of collisions with large animals in the mitigation zones has been about 50 per year in recent years, and, assuming a reduction of 87%, the mitigation measures may prevent about 44 collisions with large animals per year, relatively close to the break-even point. Similarly, for the road sections in and around Radium Hot Springs, the mitigation measures would have to prevent about 4 collisions with large animals per year to break even. The reported number of collisions with bighorn sheep has been about 10 per year in recent years, and, assuming a reduction of 87%, the mitigation measures may prevent about 9 collisions with bighorn sheep per year, substantially more than the break-even point.

The research team encourages the users of this report to be flexible with the interpretation of the proposed mitigation measures. Due to time constraints and the time of year this project was conducted, detailed field investigations and verifications were not possible (snow cover), and the research team recommends such field investigations and verifications before final decisions are made with regard to the beginning and ending of wildlife fencing and the exact location of safe crossing opportunities. In addition, in areas with long sections of wildlife fencing, one may consider modeling wildlife movements and population viability for different configurations of mitigation measures.

1. INTRODUCTION

1.1 Background

Wildlife-vehicle collisions (WVCs) affect human safety, property and wildlife, and the number of WVCs has substantially increased across much of North America over the last decades (Hughes et al. 1996, Romin & Bissonette 1996, Khattak 2003, Tardif & Associates Inc. 2003, Knapp et al. 2004, Williams and Wells 2005, Huijser et al. 2007a).

WVCs along Highway 93 South in Kootenay and Banff National Parks are a concern to Parks Canada (Parks Canada 2007). This concern of Parks Canada relates to the human safety aspect as well as the conservation of the natural resources of Kootenay and Banff National Park. Highway 93 South is a major two lane highway that extends 106 km from the Trans-Canada Highway in Banff National Park in Alberta to the Columbia Valley at Radium Hot Springs in British Columbia. Kootenay National Park is a relatively long, narrow park with Highway 93 South bisecting its major valley bottoms. Therefore, much of the park is affected by the transportation corridor (Parks Canada 2007).

Parks Canada has a management objective to reduce the death of large mammals as a result of collisions with vehicles (Parks Canada 2000). Over the last 33 years (1975 through 2007), 1,531 observations of wildlife mortality within 500m of Highway 93S in Kootenay and nearby portions of Banff National Park have been reported (Figure 1). The most frequently recorded species (those over 5% of mortalities by species) involved with WVCs are white-tailed deer (n=557; 36.4%), elk (n=332; 21.7%), mule deer (n=152; 9.9%), and moose (n=117; 7.6%), with over 23 other species each composing less than 5% of the mortalities (Figure 1, Table 1). Note that the search and reporting effort for species smaller than coyotes is unlikely to have been consistent (Personal communication, Alan Dibb, Parks Canada). Of those other species, relatively rare or sensitive species have been reported as road kill, including grizzly bear, Canada lynx, wolf, bighorn sheep ,and mountain goat (Table 1).

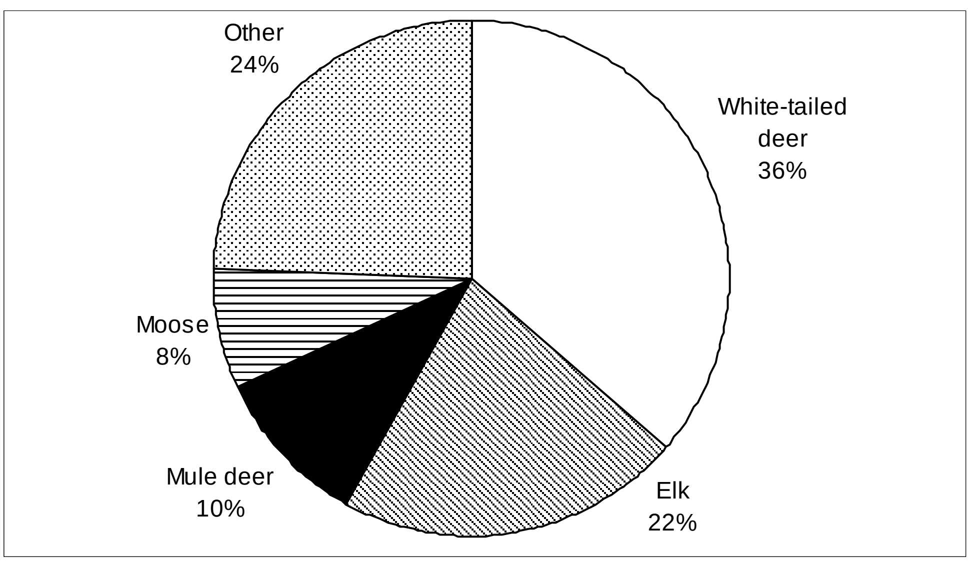

Figure 1. Relative abundance of reported road killed species in Kootenay and Banff National Park (1975 through 2007), found within 500m of Hwy 93S (N total = 1,531).

Table 1. Number and relative abundance (%) of road killed species included in the "other" category in Figure 1. The data relate to road killed wildlife in Kootenay and Banff National Park (1975 through 2007), found within 500m of Hwy 93S.

Other species	Number of Mortalities	Percentage
Coyote	70	4.57
Bighorn sheep	65	4.25
Black bear	46	3.00
Bird	35	2.29
Porcupine	35	2.29
Deer	29	1.89
Pine marten	25	1.63
Snowshoe hare	17	1.11
Wolf	14	0.91
Skunk	9	0.59
Small rodents	6	0.39
Beaver	4	0.26
Bobcat	2	0.13
Mountain goat	2	0.13
Grizzly bear	2	0.13
Herpetofauna	2	0.13
Canada lynx	2	0.13
Muskrat	2	0.13
Wolverine	2	0.13
Cougar	1	0.07
Hoary marmot	1	0.07
Red fox	1	0.07
Unknown	1	0.07
Total	373	24.36

Rapidly growing human populations in Alberta and British Columbia along with growing recreational interest in the Columbia Valley have contributed to substantial increases in traffic volume on Highway 93 South. Traffic consists mainly of through traffic, including many one-time visitors, commercial truck traffic, and recreational commuters (Parks Canada 2007). The 85 percentile of vehicle speeds in 2007 was 111 km/h, both during the day and night (Parks Canada). The majority of all vehicles in 2007 were passenger cars (total: 84%, day: 85%, night: 78%), followed by recreational vehicles (total: 10%, day: 10%, night: 7%), trucks (total: 6%, day: 5%, night: 15%), and busses (total: 0.5%, day: 0.5%, night: 1%) (Parks Canada). Traffic volume is highest during the summer months (Figure 2). Traffic volume is peaks during the day, both in winter (January-February) and in summer (July), but on weekend days traffic volume is higher in the morning, afternoon and evening compared to workdays, especially in summer (Figure 3 and 4). Large truck traffic (5% of the total traffic volume in July and 13% in November-December (Poll, 1989)) is believed to be responsible for a disproportionate number of the WVCs on Highway 93 South (Parks Canada 2007). Annual traffic volume rose from 700,000 in 1997 to 901.000 in 2006, an increase of 28.6% (Figure 5). The relatively low traffic volume in 2003 is associated with large scale fires that led to road closure in the summer (Personal communication, Alan Dibb, Parks Canada). Over the same time period, the number of reported WVCs increased from 25 (1997) to 77 (2006), an increase of 208% (Figure 5). Nonetheless, the number of reported WVC-caused mortalities has varied over time (Figure 6), probably because of a combination of variable search and reporting effort, succession and associated changes in population size of individual species (see e.g. Appendix M). Given the strong increase in traffic volume over the last decade, the relatively high numbers of road-killed wildlife and the expected further increase in traffic volume in the near future, Parks Canada is concerned about human safety and the impacts of the road and traffic on wildlife.

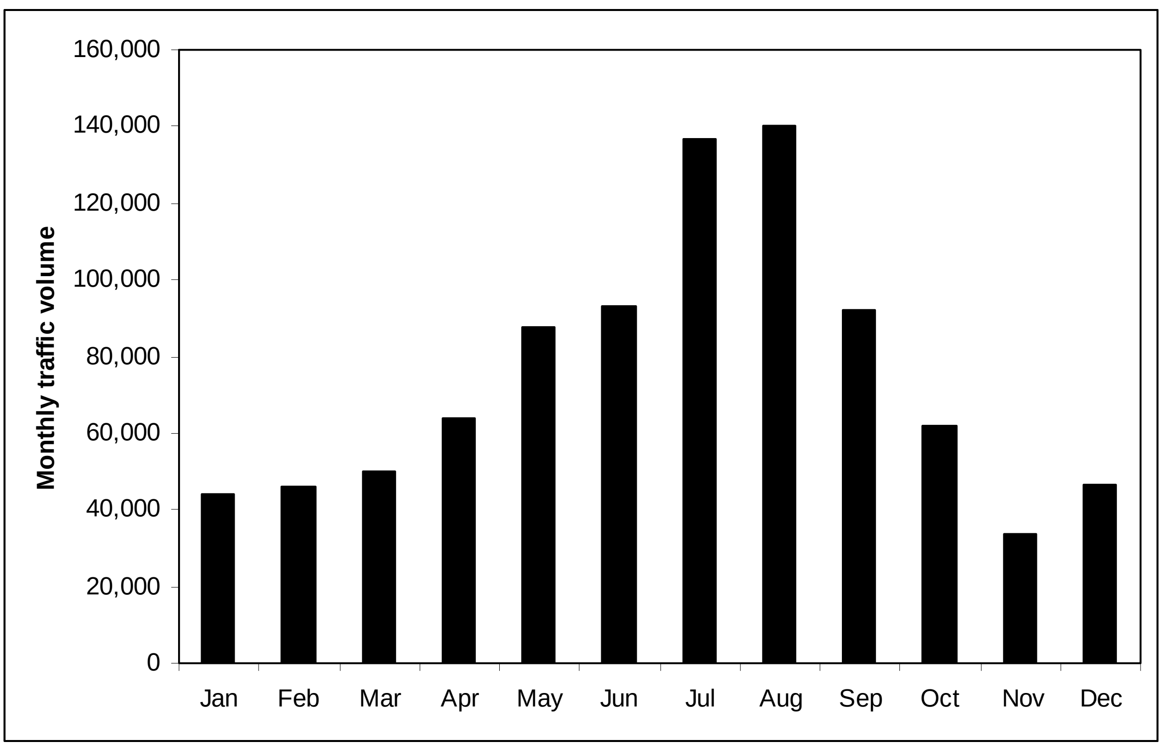

Figure 2. Monthly traffic volume in 2006 on Hwy 93S in Kootenay National Park (Data provided by Parks Canada).

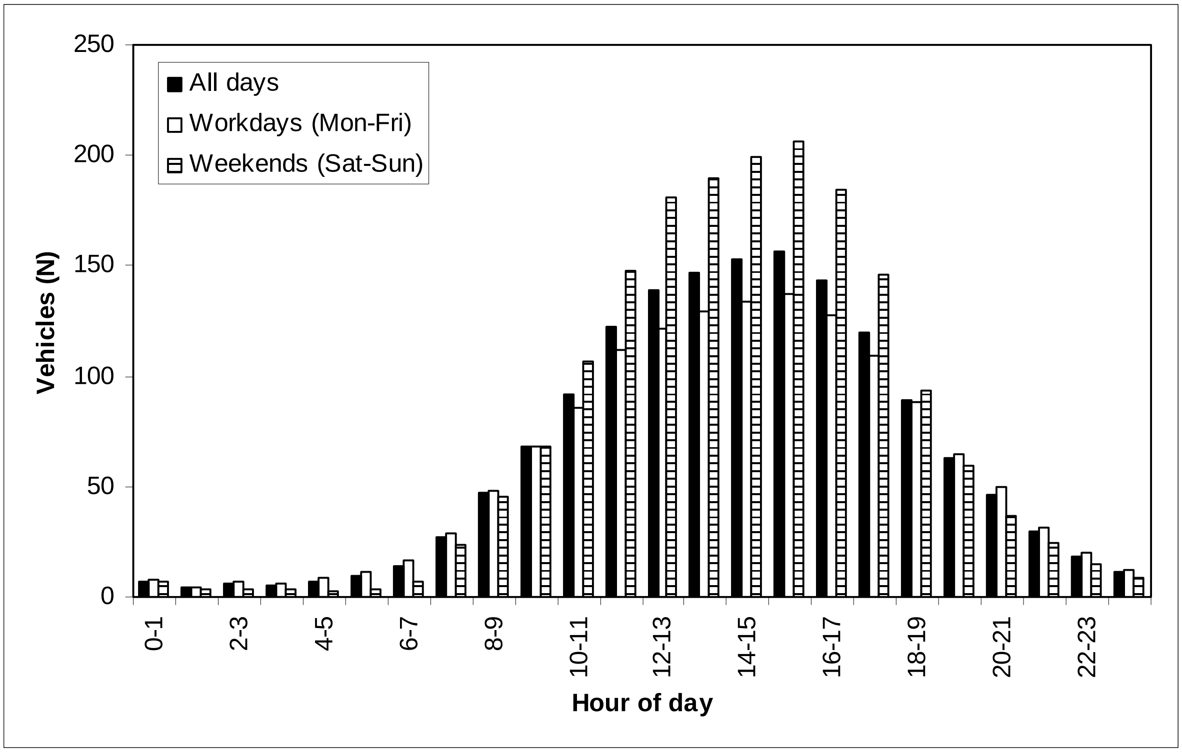

Figure 3. Hourly average traffic volume in January and February 2006 on Hwy 93S in Kootenay National Park, 6.1 km south of Castle Jct (Data provided by Parks Canada).

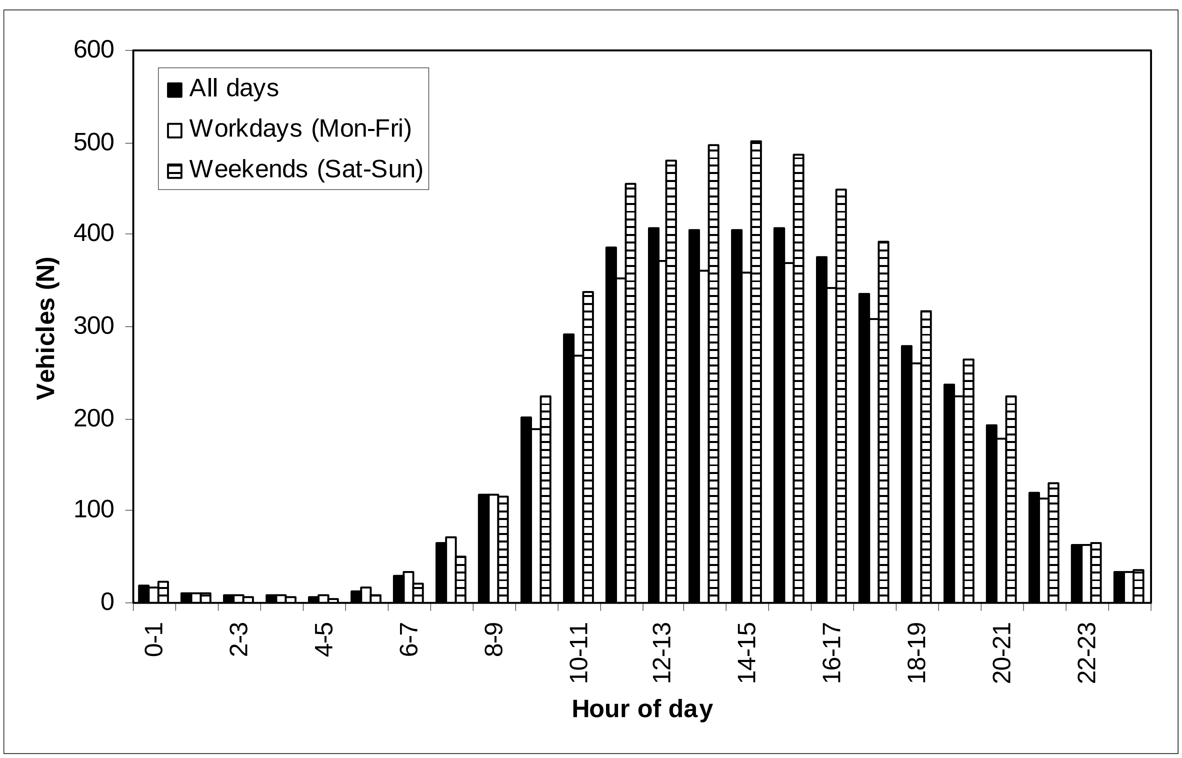

Figure 4. Hourly average traffic volume in July 2006 on Hwy 93S in Kootenay National Park, 6.1 km south of Castle Jct (Data provided by Parks Canada).

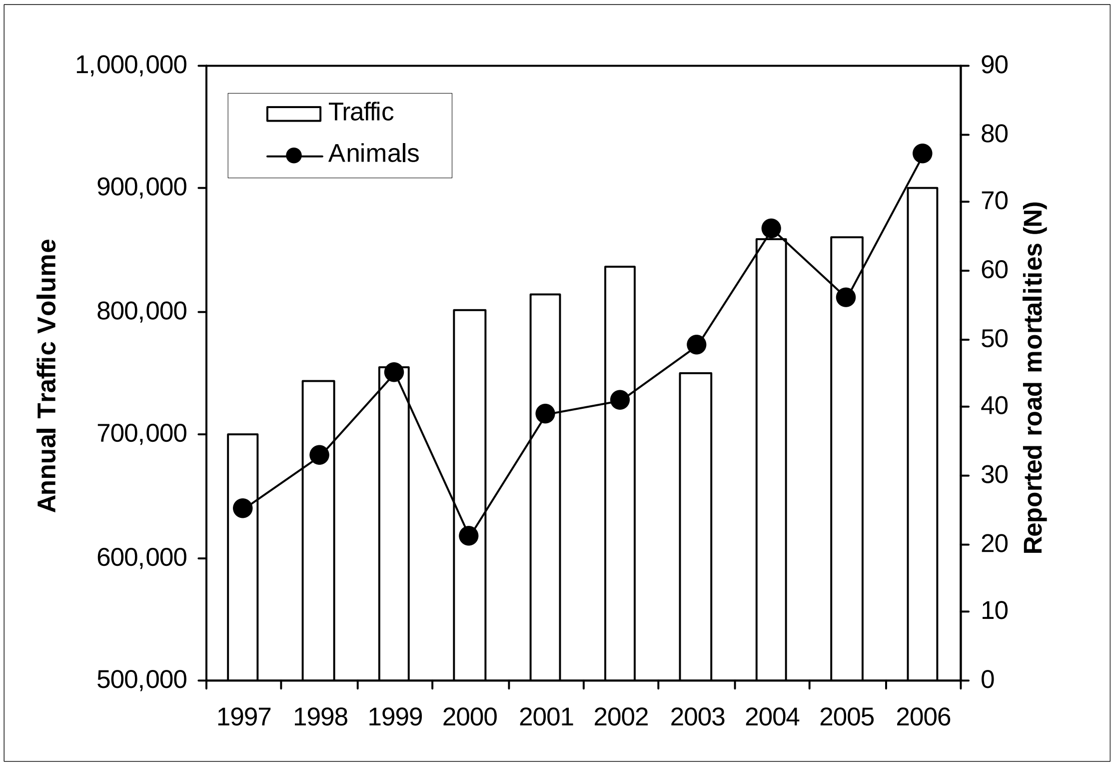

Figure 5. Annual traffic volume and number of reported road mortalities along Hwy 93S in Kootenay National Park by year (1997 through 2006) (Data provided by Parks Canada). The species included in the road mortality counts are white-tailed deer, mule deer, elk, moose, mountain goat, bighorn sheep, bobcat, Canada lynx, red fox, coyote, wolf, black bear, and grizzly bear.

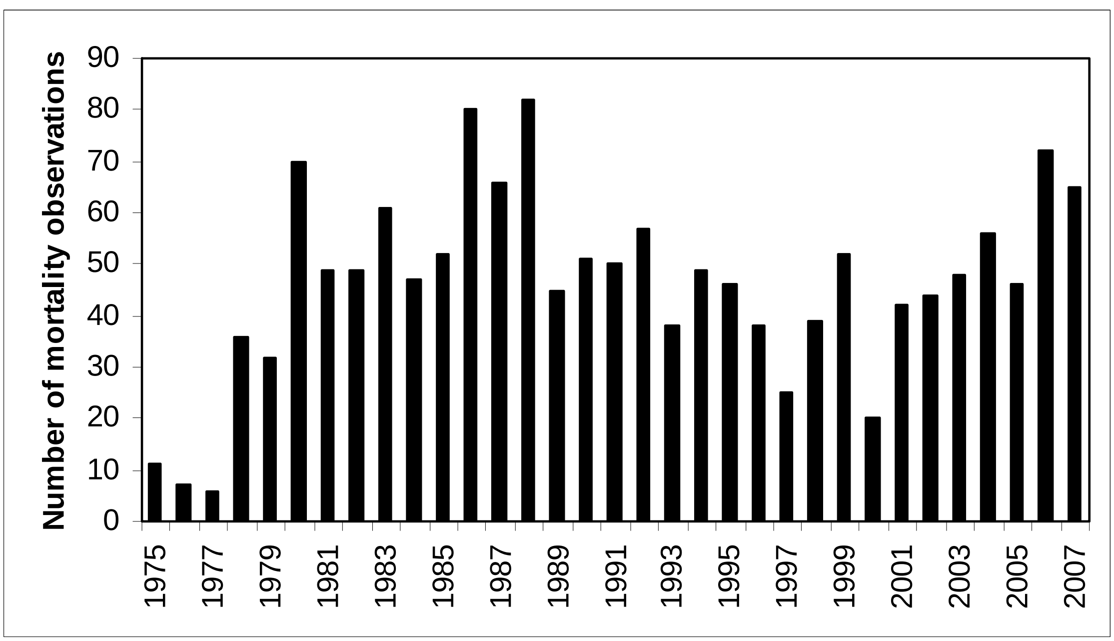

Figure 6. Number of reported road mortalities, regardless of the species, in Kootenay and Banff National Park by year (1975 through 2007), found within 500m of Hwy 93S.

Parks Canada asked the Western Transportation Institute at Montana State University (WTI) to investigate and recommend strategies that reduce WVCs and that maintain or improve habitat connectivity for wildlife. The specific tasks of the work included:

- Review mitigation measures aimed at reducing WVCs and at maintaining or improving habitat connectivity for wildlife;
- Identify and prioritize road sections for potential mitigation measures;
- Develop a mitigation plan;
- Review funding mechanisms and potential partnerships for the implementation of the mitigation measures; and
- Produce a Final Report on the abovementioned tasks.

Huijser and Paul (2008) reviewed mitigation measures aimed at reducing WVCs and at maintaining or improving habitat connectivity for wildlife. This manuscript addresses the remaining tasks. It identifies and prioritizes road sections for potential mitigation measures, provides a mitigation plan aimed at reducing wildlife-vehicle collisions and providing safe wildlife crossing opportunities, and reviews potential funding mechanisms for such mitigation measures.

Parks Canada provided specific guidelines for this project. The highway mitigation plan for the study area may not be carried out in its entirety at the same time. Therefore, Parks Canada requested that the mitigation measures be prioritized by certain road segments. These segments are: Vermilion Pass – Castle Junction; Vermilion Valley; Kootenay Valley; Sinclair Creek and Canyon; and the roads in and around Radium Hot Springs (Highways 93 and 93/95) (Parks Canada 2007). Parks Canada also required that the mitigation plan should not include wildlife fencing for the entire length of the road through Kootenay and Banff National Park and that the road sections in and around Radium Hot Springs should be treated separately from the road through Kootenay and Banff National Park as the latter roads are managed by a different highway authority (British Columbia Ministry of Transportation).

1.2 Study Area

As described in the terms of reference (Parks Canada 2007), the study area includes Highway 93 South from Castle Junction in Banff National Park to the intersection with Highway 95 in Radium Hot Springs, B.C., and sections 4 km north (Hwy 95) and south (Hwy 93/95) of this intersection (Figure 7 and 8). In this report, we distinguish between 2 major road segments:

- The Kootenay/Banff section: Highway 93S through Kootenay (92.9 km) and Banff (9.9 km) National Park (from the boundary of Kootenay National Park near Radium Hot Springs until the junction with the Trans-Canada Highway (Castle Jct).
- The road sections in and around Radium Hot Springs:
    - Radium Hot Springs East: Highway 93S from the junction with Highway 95 in Radium Hot Springs until the boundary of Kootenay National Park (1.1 km).
    - Radium Hot Springs South: Highway 93/95 from the junction with Highway 95 in Radium Hot Springs until 4.0 km south of Radium Hot Springs (4.0 km).

- Radium Hot Springs North: Highway 95 from the junction with Highway 95 in Radium Hot Springs until 4.0 km north of Radium Hot Springs (4.0 km).

The road sections in and around Radium Hot Springs are outside Banff and Kootenay National Park. However, Parks Canada included these road sections in the study area (Parks Canada 2007) as the area surrounding these road sections are a major part of the winter range of the largest and most productive bighorn sheep population, a blue-listed species in British Columbia (Dibb 2006), in Kootenay National Park. This herd migrates to low elevation habitat outside Kootenay National Park in winter, and is highly susceptible to highway collisions along provincial Highway 93/95 just south of the village of Radium Hot Springs (Parks Canada 2007). Here bighorn sheep not only cross hwy 93S as they move between different parts of their winter range, but the sheep also spent substantial time licking road salt in winter (Personal communication, Alan Dibb, Parks Canada). In and around Radium Hot Springs, 84 (93.3 %) road-killed bighorn sheep, 5 (5.6%) road killed mule deer, and 1 (1.1%) road killed elk have been reported (1975 through 2007) (Figure 9) and this number has increased over time (Figure 10).

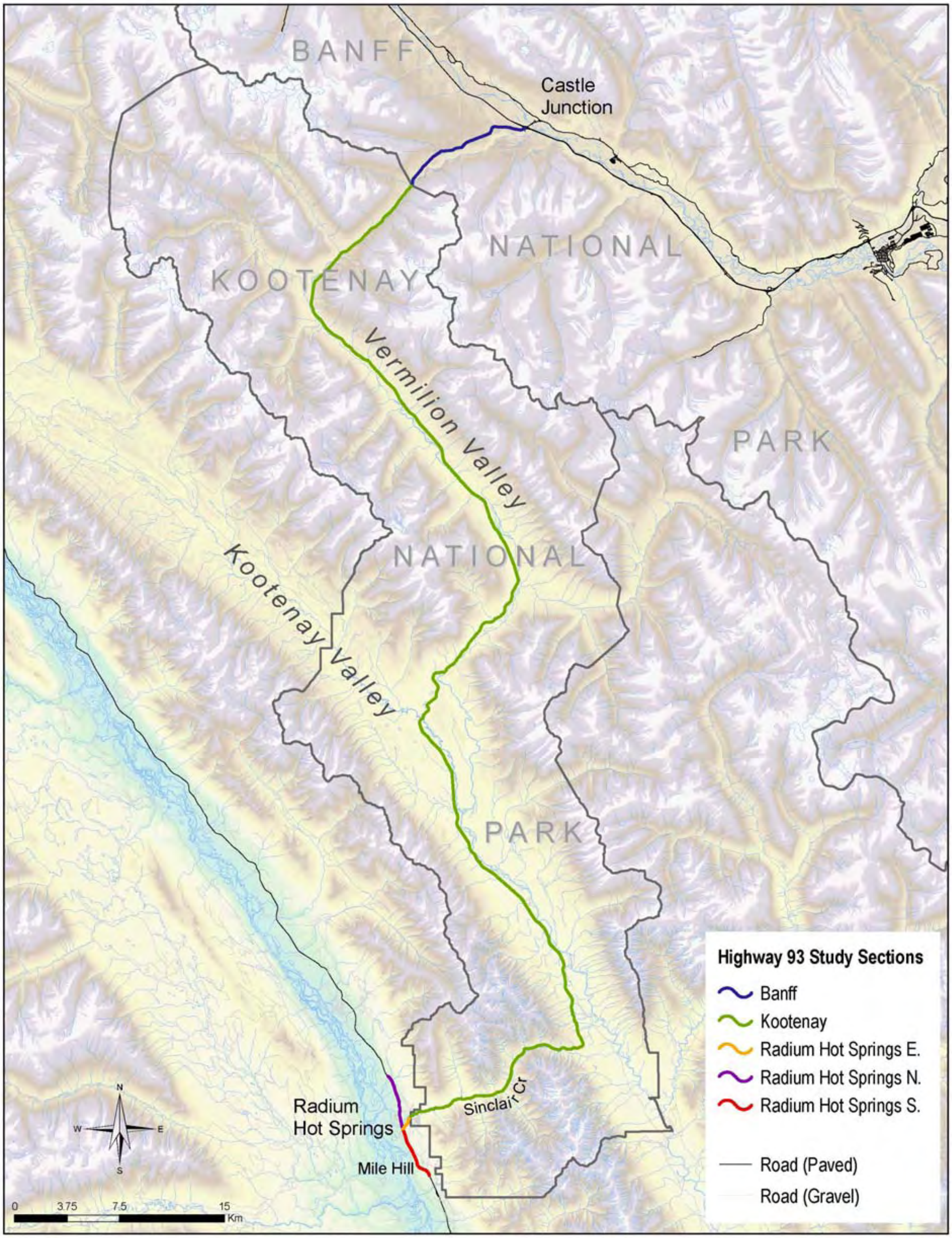

Figure 7. The study area and the road segments in the study area. The road sections in the study area include Hwy 93S from Castle Jct in Banff National Park until the intersection of Hwy93/95 in Radium Hot Springs and 4 km north (Hwy 95) and south (Hwy 93) of this intersection.

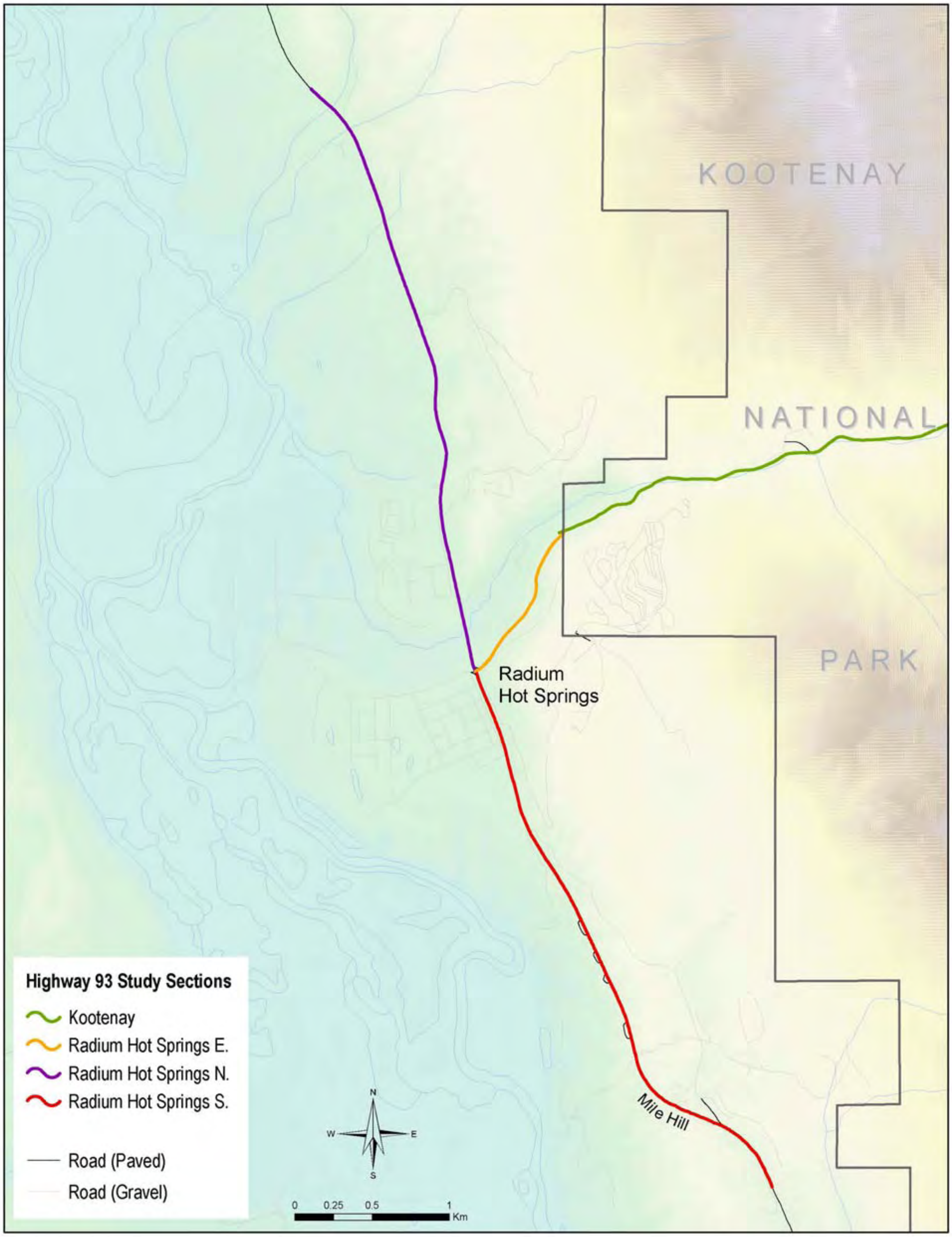

Figure 8. The road segments in and around Radium Hot Springs (see also Figure 3).

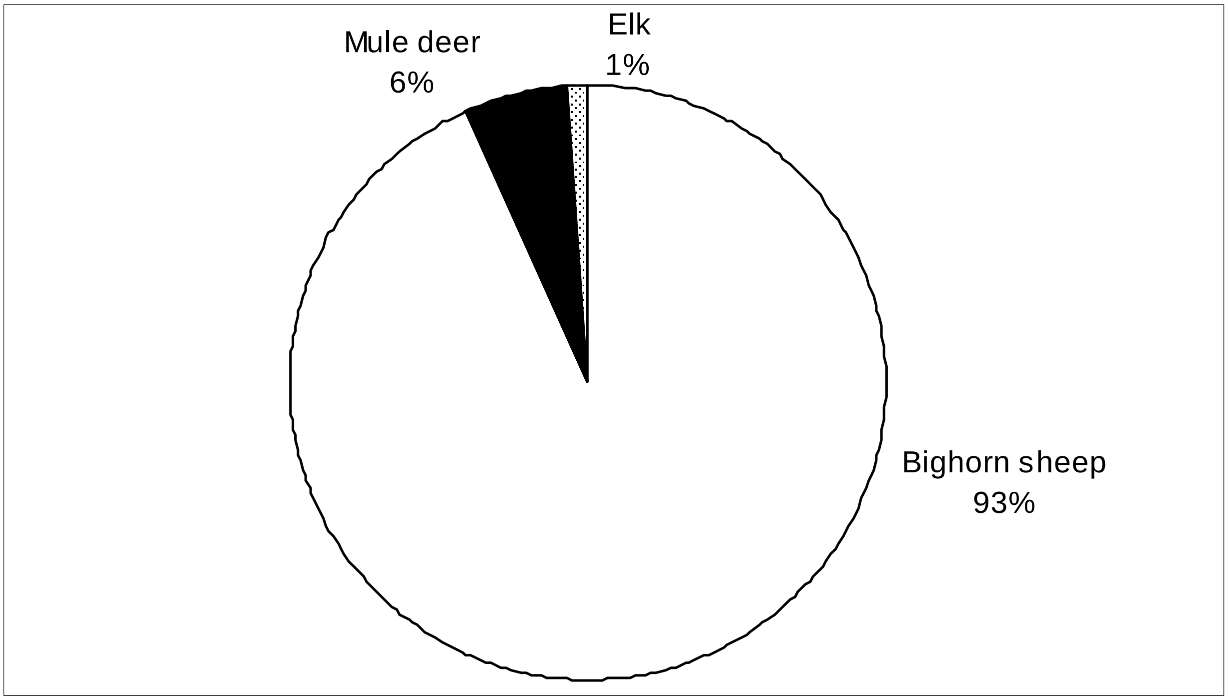

Figure 9. Relative abundance of reported road killed species in and around Radium Hot Springs (1975 through 2007), found within 500m of Hwy 93/95 (N total = 90).

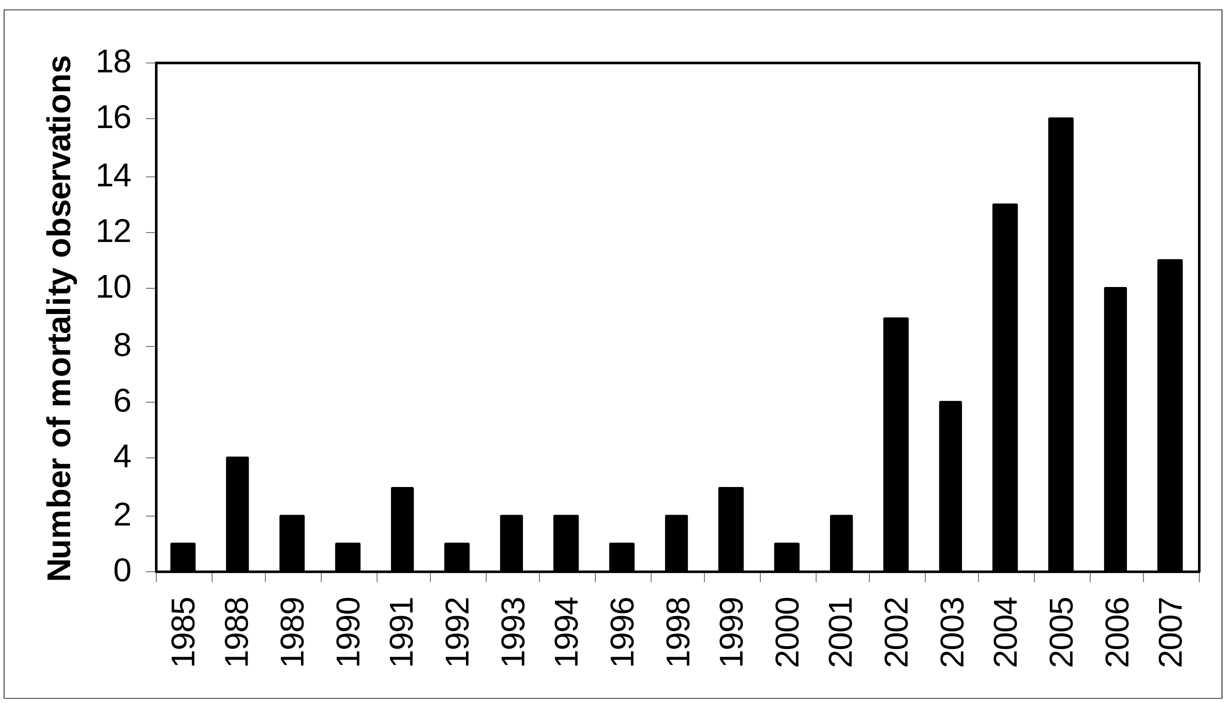

Figure 10. Number of reported road mortalities, regardless of the species, on and along the road sections in and around Radium Hot Springs by year (1975 through 2007), found within 500m of Hwy 93/95.

The bighorn sheep spend substantial time on the golf course and in residential areas within the Village of Radium Hot Springs (Personal Communication, Alan Dibb, Parks Canada). The golf course is now an important food source to the bighorn sheep and the presence of bighorn sheep in Radium Hot Springs and their habituation to people is a concern to Parks Canada. Parks Canada has been conducting vegetation management east of Hwy 93S, south east of Radium Hot Springs, which provides an alternative food source to wintering bighorn sheep in the area (Figure 11).

The bighorn sheep in and around Radium Hot Springs attract public attention, as they are highly visible in the village and along the roads leading to the village (Figure 12 through 14). They have become a tourist attraction for visitors interested in wildlife viewing. The Radium Hot Springs Chamber of Commerce has developed a bighorn sheep viewing program during the rutting season ("Head Banger Tours") to attract visitors. Bighorn sheep viewing provides an economic benefit to the local community. Kootenay National Park itself also provides an economic benefit to Radium Hot Springs. As a "gateway community" to the park, tourists take advantage of the services within Radium Hot Springs, the hot spring pools inside the park, and new residents have been moving to the area, resulting in additional local economic growth.

Figure 11. Open forest/grassland restoration area, just east of Radium Hot Springs (© Marcel Huijser).

Figure 12. Bighorn sheep along Hwy 93, on Mile Hill, just south of Radium Hot Springs (© Marcel Huijser).

Figure 13. Bighorn sheep crossing Hwy 93, on Mile Hill, just south of Radium Hot Springs (© Marcel Huijser).

Figure 14. Bighorn sheep crossing Hwy 93, "pushed" by oncoming vehicle, on Mile Hill, just south of Radium Hot Springs (© Marcel Huijser).

To summarize, Parks Canada has expressed an interest in reducing road mortality for bighorn sheep in and around Radium Hot Springs. In addition, while the bighorn sheep are an important attractant to visitors in and around Radium Hot Springs, Parks Canada would like to provide more natural winter range (an alternative to the golf course) for bighorn sheep and reduce habituation to and conflicts with people in this area.

1.3 Previous Efforts

Parks Canada has, in the past, implemented a variety of measures intended to reduce highway mortality, as described by Preston et al. (2006). Many of these measures were recommended by Poll (1989), although not all of Poll's recommendations were implemented. In addition, in 2002 and 2003 a wildlife detection system was implemented and evaluated on 93S in the Kootenay Valley (Kinley et al. 2003a, 2003b). However the system was taken out due to technical problems that needed to be resolved prior to the product becoming commercially available (Huijser et al. 2006, Parks Canada 2007). Previous efforts examining aspects of wildlife mortality on the highway in KNP include:

- Dibb, A. 2006. Seasonal Habitat Use and Movement Corridor Selection of Rocky Mountain Bighorn Sheep (*Ovis canadensis*), Near Radium Hot Springs, British Columbia. 2002-04 Progress Report. Parks Canada Agency, Lake Louise, Yoho and Kootenay Field Unit. Radium Hot Springs, B.C.
- Kinley, T.A., H.N. Page, and N.J. Newhouse. 2003a. Use of Infrared Camera Video Footage From a Wildlife Protection System to Assess Collision-risk Behavior by Deer in Kootenay National Park, British Columbia. Unpublished report prepared for Insurance Corporation of British Columbia, Kamloops, BC. 10 pp. Available at: http://www.wildlifeaccidents.ca/SiteCM/U/D/68770B4D8C6AB753.pdf.

- Kinley, T.A., N.J. Newhouse, and H.N. Page. 2003b. Evaluation of the Wildlife Protection System Deployed on Highway 93 in Kootenay National Park During Autumn, 2003. Unpublished report prepared for Insurance Corporation of British Columbia, Kamloops, BC. 18 pp.
- Olsson, E.S. 2002. Wolves, *Canis lupus*, Road Crossings in Kootenay National Park, Canada: Choice of Crossing Locations. External Degree Project, Stockholm University, Stockholm,Sweden. Available at: http://home.bip.net/gustav.tillback/EXAMENSARBETE_KOOTENAY.doc.
- Poll, D.M. 1989. Wildlife Mortality on the Kootenay Parkway, Kootenay National Park. Environmental Canada, Canadian Parks Service, Radium Hot Spring, BC.
- Preston, M.I., L. Halverson, and G. Hesse. 2006. Mitigation Efforts to Reduce Mammal Mortality on Roadways in Kootenay National Park, British Columbia. Wildlife Afield 3 (1): 28-38.

2. GENERAL APPROACH

The researchers used wildlife road mortality data provided by Parks Canada to identify road sections that may require mitigation to reduce wildlife-vehicle collisions. Wildlife fencing and wildlife underpasses and overpasses are among the most effective mitigation measures (Huijser & Paul 2008) and form an important part of this highway mitigation plan (see Chapter 7). Because of the relatively long life span of these mitigation measures (fences 25 years; underpasses and overpasses 75 years), the identification of road sections that may require mitigation should reflect the dynamics of the ecosystem over a similar period. Such dynamics include large scale habitat changes as a result of natural succession, fire, and associated changes in the population size and distribution of species of interest. For example, over the last decades natural succession has led to fewer and smaller meadows in the Kootenay Valley, large scale fires burned in the Vermilion Valley in 2001 and 2003, and elk population size in the Park has substantially declined between the late 1980s until the mid 1990s (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). The decline in the elk population is thought to be the result of a number of factors including habitat change, human-caused mortality (especially road mortality), and competition with domestic livestock for low elevation winter range (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). Such changes the landscape and wildlife populations are likely to influence the location and number of wildlife-vehicle collisions, and the species involved. Therefore, the identification of road sections that may require mitigation should preferably be based on data covering a relatively long time period.

Wildlife road mortality data for the road sections in our study area are managed by Parks Canada. These data are considered reliable from 1975 onwards (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). The researchers based the identification of road sections that may require mitigation on road mortality data from 1975 through 2007; a data set spanning 33 years. The researchers recognize that even though this is a relatively long time period, the data may not reflect all the potential changes in the location and number of wildlife-vehicle collisions, nor the species involved, over the life span of some of the mitigation measures. Nonetheless, the risk of investing in mitigation measures at the wrong location, or designing them for the wrong species, is substantially reduced by using data that cover a relatively long time period.

The researchers recognize that not all of the funds required to implement the suggested mitigation measures (see Chapter 7) may be available on short term (see also Parks Canada 2007). Therefore the prioritization of road sections that require mitigation is essential. The prioritization of the road sections is based on wildlife road mortality data covering a much shorter time period, ten years (1998 through 2007), than the data used to identify these road sections (1975 through 2007). This means that the available funds are first invested at locations that have shown the most road mortality in recent years, and where relatively high and immediate returns on the investments are most likely. At the same time, the risk of investing in a site that may not be a substantial problem over a long time period is minimized because the identification of these road sections is based on a relatively long time period.

The wildlife road mortality data managed by Parks Canada are based on observations by personnel from Parks Canada (e.g. Park wardens, road maintenance personnel), the public, and other sources (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). The search and reporting effort has not been constant over the years (Personal Communication, Alan

Dibb and Shelagh Wrazej, Parks Canada), and spatial accuracy was much improved after Global Positioning System (GPS) units were distributed in 2002 to Parks Canada personnel (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). Changes in search and reporting effort over the years do not necessarily influence the process used to identify road sections that require mitigation. It is only when wildlife road kill is more likely to be reported on certain road sections than others that it influences the results. While the vast majority of the available wildlife road mortality data are not the result of a monitoring program with similar or documented search and reporting effort for different road sections, we do have reasons to assume that search and reporting effort was more or less similar for the road sections in Kootenay and Banff National Park (see Figure 7). There are no side roads (except for a logging and mining road (Settler's road) in the Kootenay Valley that is little used by Park personnel and the public), and observers are likely to have traveled long distances within the two Parks. On the other hand, the road sections east, south and north of Radium Hot Springs (see Figure 7 and 8) are likely to have experienced different search and reporting effort because these road sections are outside the Park, people are likely to have traveled shorter distances because of the presence of the town and the hot spring pools, and there have been efforts specifically targeted at recording observations on bighorn sheep (dead and alive). For these reasons, the road sections in Kootenay and Banff National Park were analyzed separately from the road sections in and around Radium Hot Springs. In addition, treating the road sections in and around Radium separately from the road sections in Kootenay and Banff National Park is practical because of the following reasons:

- The funding and implementation of mitigation measures for the road sections in and around Radium Hot Springs is subject to different processes than those for the road sections in Kootenay and Banff National Park as the roads in and around radium Hot Springs are managed by the British Columbia Ministry of Transportation);
- The vast majority of all reported wildlife road mortality data for the road sections in and around Radium Hot Springs relates to bighorn sheep, and;
- Parks Canada has expressed a specific interest in reducing road mortality for this population that shifts between Park lands (mostly summer range) and lands in and around Radium Hot Springs (mostly winter range) (Personal Communication, Alan Dibb, Parks Canada) (see Section 1.2).

Wildlife fencing is among the most effective mitigation measures to reduce wildlife-vehicle collisions (Huijser & Paul 2008) and forms an important part of this highway mitigation plan (see Chapter 7). However, wildlife fencing alone increases the barrier effect of a road substantially and the most effective types of fencing are close to an absolute barrier for the species that is to be prevented from entering the roadway. Therefore, wildlife fencing, and other measures that increase the barrier effect of a road, should typically be combined with safe crossing opportunities for wildlife. Such crossing opportunities may consist of wildlife underpasses or overpasses, or at grade crossing opportunities, with or without additional measures such as permanent warning signs or animal detection systems (Huijser & Paul 2008).

The location of potential safe crossing opportunities was based on both mortality data along the road (including road mortality, but not restricted to road mortality) (1975 through 2007) and incidental observations of animals seen alive on or near the road (1975 through 2007). The incidental observation data are managed by Parks Canada and are based on observations by personnel from Parks Canada (e.g. Park wardens, road maintenance personnel), the public, and other sources (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). The search and reporting effort for incidental observations from wildlife seen alive on or along the road is likely to have been inconsistent (Personal Communication, Alan Dibb and Shelagh Wrazej, Parks Canada). Since most of the staff from Parks Canada is based in Radium Hot Springs, the search and reporting effort is likely to have been greater in the south than the north. However, this does not apply so much to (road) mortality observations as all reported carcasses are attended (and documented) regardless of the distance to Radium Hot Springs.

The incidental observations were supplemented with data from a Parks Canada driving survey performed four times in one week each month from June to December 2007 within the Kootenay Valley. During the survey, personnel recorded observations of animals seen alive on or near the road. In addition, the decisions for the potential locations and design of safe crossing opportunities were influenced by data from other studies and data obtained through interviewing personnel from Parks Canada who spend considerable time along the entire length of the road through Kootenay and Banff National Park (personnel interviewed: Alan Dibb, Wildlife Specialist, Lake Louise, and Yoho and Kootenay National Parks, Drew Sinclair, Highway Operations Supervisor) (see Chapter 6). The combined mortality and incidental observation data showed where most wildlife has been observed on or close to the road (1975 through 2007), regardless of whether the individuals were dead or alive. Using both mortality and incidental observations of wildlife seen alive reduces the risk of providing safe crossing opportunities at the wrong locations, as wildlife road kill road sections are not necessarily the same locations where wildlife cross the road most frequently (Clevenger et al. 2002).

The spatial resolution of the data presented in this manuscript is 100 m. This resolution recognizes a certain degree of spatial error or imprecision with the wildlife road mortality data (see e.g. Clevenger et al. 2002) and the incidental observations data. At the same time, this resolution is precise enough and sufficiently practical with regard to the location of potential mitigation measures.

3. IDENTIFICATION OF WILDLIFE MORTALITY ROAD SECTIONS

3.1 Species and Maximum Distance from Road

Wildlife mortality data (1975 through 2007) were provided by Parks Canada. The researchers selected known wildlife road mortalities from this data set, excluding “vehicle strikes” (possible wildlife mortality), and mortalities with unknown causes or causes not resulting from a collision with a vehicle. In addition, for the road sections in Kootenay and Banff National Park, the researchers selected large ungulates and large and medium sized carnivores that either pose a threat to human safety or are of conservation interest to the Wildlife Specialist of Kootenay National Park (Table 2) (Personal Communication, Alan Dibb, Parks Canada).

For the road sections in and around Radium Hot Springs, the researchers only selected observations of bighorn sheep because:

- Data collection in and around Radium Hot Springs has been specifically directed at bighorn sheep, especially since at least the early 1990s (Personal Communication, Shelagh Wrazej, Parks Canada).
- Bighorn sheep in and around Radium Hot Springs area are the species of most interest to Parks Canada (see also Section 1.2 and Chapter 2).
- The vast majority (93.3%) of all wildlife road mortality records in and around Radium Hot Springs related to bighorn sheep anyway (see Figure 9).

Table 2. Species Selected for the Identification of Wildlife Mortality Road Sections.

Large ungulates	**Large and medium carnivores**
White-tailed deer (*Odocoileus virginianus)*	Wolverine (*Gulo gulo)*
Mule deer (*Odocoileus hemionus)*	Bobcat (*Lynx rufus)*
Elk (*Cervus elaphus*)	Canada lynx (*Lynx canadensis)*
Moose (*Alces alces)*	Cougar (*Puma concolor)*
Mountain goat (*Oreamnos americanus*)	Coyote (*Canis latrans)*
Bighorn sheep (*Ovis canadensis*)	Wolf (*Canis lupus*)
	Black bear (*Ursus americanus)*
	Grizzly bear (*Ursus arctos*)

The selected observations were plotted within a Geographical Information System GIS (ESRI ArcGIS 9.2). Not all wildlife road mortality observations were located on or directly adjacent to the roadway as wounded animals sometimes wander off before dying. In addition, observers may have made an error or may have been imprecise when documenting the location of the animal. The researchers assumed that the location of road killed wildlife, at least on average, was close to the location of the actual collision. The researchers recognized however that the potential for a spatial mismatch between the location of road killed wildlife and the location of the actual collision increases with the distance to the road. Therefore the researchers measured the shortest possible distance from each observation location to the road and only selected those observations that were within 100 m of the road. Nonetheless, Parks Canada Agency (PCA) has gone through considerable effort to ensure that the data in the database are accurate (Personal Communication, Alan Dibb, Parks Canada). Coordinates were compared to location descriptions, and observers were re-interviewed to resolve discrepancies.

For the road sections in Kootenay and Banff National Park and for the species listed in Table 2, the majority of road mortalities reported within 100 m from the road related to ungulates (Figure 15 and Table 3). For the road sections in and around Radium Hot Springs there were 71 observations of bighorn sheep within 100 m of the study area section.

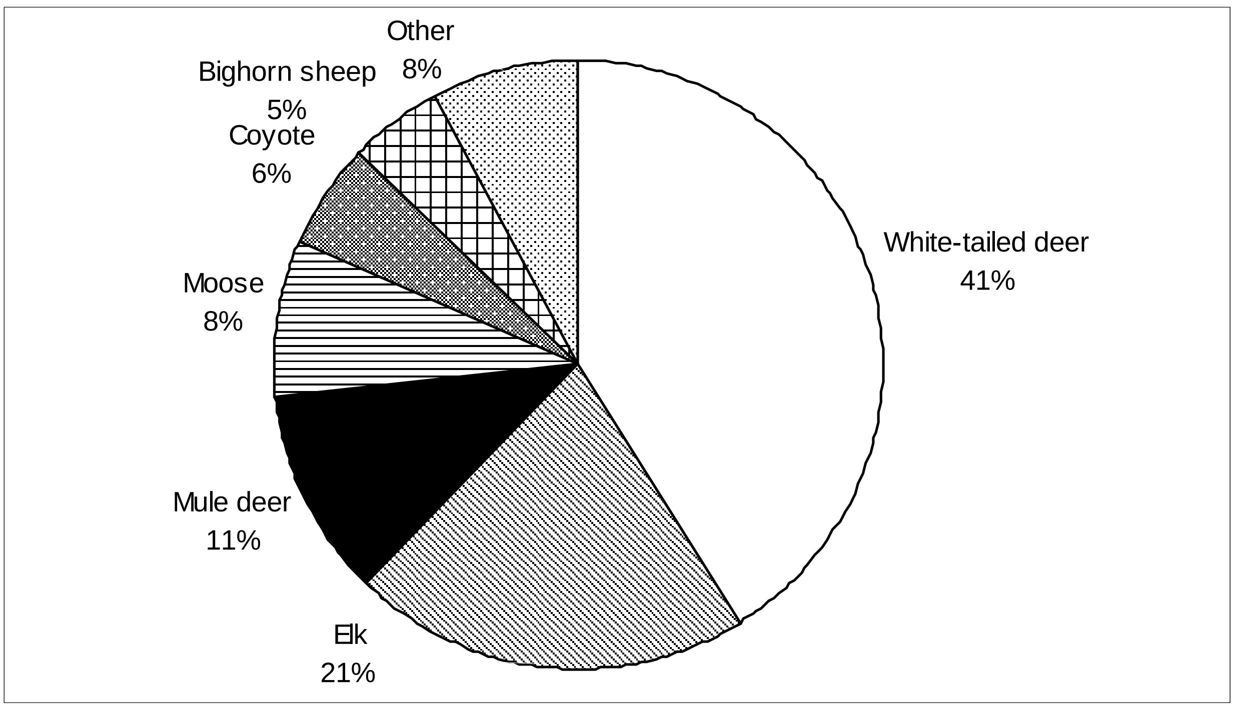

Figure 15. Relative abundance of reported road killed species (species listed in Table 2 only) on the road sections in Kootenay and Banff National Park (1975 through 2007), found within 100m of Hwy 93S (N total = 1,088).

Table 3. Number and relative abundance (%) of road killed species (species listed in Table 2 only) included in the "other" category in Figure 15. The data relate to road killed wildlife in Kootenay and Banff National Park (1975 through 2007), found within 100m of Hwy 93S.

Other species	Number of Mortalities	Percentage
Black bear	41	3.77
Deer	27	2.48
Wolf	9	0.83
Mountain goat	2	0.18
Grizzly bear	2	0.18
Canada lynx	2	0.18
Wolverine	2	0.18
Total	85	7.81

3.2 33 Year Mortality Clusters

The roads in the study area were divided into 100 m long road units (see Appendix A Topographic maps with 100 m road units). The researchers distinguished five different road sections (see also Figure 7 and 8) that each had their own numbering system for these 100 m long road units:

- Banff (10.0 km in length): start (0.0 km point) coincides with the junction with the Trans-Canada Highway in Banff National Park (Castle Jct); end (9.9 km road unit) coincides with the boundary between Banff and Kootenay National Park.
- Kootenay (92.9 km in length): start (0.0 km point) coincides with the southern boundary of Kootenay National Park near Radium Hot Springs; end (92.8 km road unit) coincides with the boundary between Banff and Kootenay National Park.
- Radium Hot Springs East (1.1 km in length): start (0.0 km point) coincides with the junction of Highway 93 and Highway 95 in Radium Hot Springs; end (1.0 km road unit) coincides with the boundary of Kootenay National Park.
- Radium Hot Springs South (4.0 km in length): start (0.0 km point) coincides with the junction of Highway 93 and Highway 95 in Radium Hot Springs; end (3.9 km road unit) is 4.0 km south of the junction.
- Radium Hot Springs North (4.0 km in length): start (0.0 km point) coincides with the junction of Highway 93 and Highway 95 in Radium Hot Springs; end (3.9 km road unit) is 4.0 km north of the junction.

All selected wildlife road mortality observations (see section 3.1) were "snapped" to the nearest 100 m long road unit using a GIS (ESRI ArcGIS 9.2). The number of road mortality observations was summed for each 100 m unit (see Appendix B, C, D). Road sections with a concentration of wildlife mortality (“33 year mortality clusters”) were identified separately for the road sections in Kootenay and Banff National Park and the road sections in and around Radium Hot Springs (see also Chapter 2).

The procedure for the road sections in Kootenay and Banff National Park was as follows:

- No distinction was made between the different species; all focal species (see Table 2) were weighted equally. The number of observations in each 100 m long road unit reflects the total number of wildlife road mortality observations, regardless of the species, in or adjacent (maximum distance from road is 100 m) to that 100 m long road unit.
- For each 100 m long road unit, a “wildlife road mortality value” was calculated by taking the sum of the unit concerned and its two neighboring units. For example, if adjacent 100 m long units had the following number of observations: 0, 1, 3, 2, 4, 2, 0, the “wildlife road mortality value” for these 100 m units was (?+1), 4, 6, 9, 8, 6, (2+?) (see also Appendix B and C (Kootenay and Banff sections). Thus the “wildlife road mortality value” for each 100 m road unit was related to the number of mortality observations in a 0.3 km road length section. This procedure recognized that an observation may have actually occurred in the neighboring 100 m road unit (potential spatial errors or spatial imprecision of observers) and it provided for a variable with values with a smoother transition between adjacent 100 m road units as the “wildlife road mortality value” for each 100 m unit was also influenced by its two neighboring units.
- Six categories of the “wildlife road mortality values” were distinguished for the 100 m road units. The cut-off levels for these categories were determined using the following procedure:
    - 100 m units with a “0” wildlife road mortality value were classified as “absent” (Table 4).
    - The remaining 100 m units had a wildlife road mortality value of 1 or greater and the researchers calculated the 20, 40, 60 and 80 percentiles and classified each of the 100 m units as one of the following: “very low” (>0-20%), “low” (20-40%), “medium” (40-60%), “high” (60-80%), and “very high” (80-100%) (Table 4).

The procedure for the road sections in and around Radium Hot Springs was as follows:

- The road sections in and around Radium Hot Springs only related to bighorn sheep (see section 3.1). The number of observations in each 100 m long road unit reflects the total number of bighorn speed road mortality observations in or adjacent (maximum distance from road is 100 m) to that 100 m long road unit.
- For each 100 m long road unit, a “bighorn sheep road mortality value” was calculated by taking the sum of the unit concerned and its two neighboring units (see procedure for road sections in Kootenay and Banff National Park and see Appendix D (road sections in and around radium Hot Springs).

- Using a similar procedure as described for the road sections in Kootenay and Banff National park, six categories of the "bighorn sheep road mortality value" were distinguished (Table 4).

Table 4. Cutoff levels of "wildlife road mortality values" for the road sections in Kootenay and Banff National park, and the "bighorn sheep road mortality values" for the road sections in and around Radium Hot Springs.

Road Sections	Absent	Very low	Low	Medium	High	Very high
Kootenay/Banff	0	1	2	3	4 – 5	6 – 28
Radium	0	1	2	3	4 – 7	8 – 18

The researchers identified "33 year mortality clusters" by marking all 100 m road units categorized as "very high" (Appendix B, C, D). If a 100 m road unit marked as "very high" had adjacent units that were classified as "high", these units were marked as well (Appendix B, C, D). The "marking" on either side of a 100 m road unit classified as "very high" stopped when a 100 m road unit occurred that was classified as "medium" or lower. If a 100 m road unit classified as "high" was not adjacent to a 100 m road unit classified as "very high" it was not included in any of the mortality 33 year mortality clusters. Thus, "33 year road mortality clusters" consisted of the "worst 20%" of all 100 m road units (excluding the 100 m road units that were classified as "absent") and the adjacent 100 m units, as long as these fell within the "worst 40%" (excluding the 100 m road units that were classified as "absent") (Appendix B, C, D). Note that the 33 year mortality clusters were based on a 33 year long time period (1975 through 2007). The location of the 33 year mortality clusters is relatively robust and is based, at least to a certain extent, on the dynamics in the ecosystem, for example natural succession, fire, and changes in the population size of certain species.

3.3 Buffer Zones, Gaps, and Mitigation Zones

For each 33 year mortality cluster in Kootenay and Banff National Park, the researchers calculated the percentage of each species based on the underlying wildlife road mortality observations (Appendix E). These data showed the researchers what species wildlife-vehicle collision reduction measures should be designed for, for each 33 year mortality cluster. The wildlife observations for the road sections in and around Radium Hot Springs related to bighorn sheep only because of the data selection procedure (see section 3.1).

White-tailed deer were the most abundant reported species killed in the study area (see Figure 1 and 15). White-tailed deer are thought to be attracted to the road corridor because of the grass-herb vegetation in the right-of-way, especially in the Kootenay Valley (Alan Dibb, Parks Canada, personal communication). If wildlife road mortality in 33 year mortality clusters is reduced through the installation of e.g. wildlife fencing, wildlife that is attracted to the right-of-way vegetation may still gain access to this vegetation at fence ends. Such behavior would result in a change in location of wildlife-vehicle collisions rather than a reduction in wildlife-vehicle collisions. Therefore wildlife fencing and other measures that keep wildlife away from the right-of-way vegetation should have buffer zones that extend beyond the location of the 33 year mortality clusters. Since white-tailed deer are the most frequently reported species in the road mortality database, and since they are thought to be especially attracted to the right-of-way vegetation, the researchers applied a buffer zone on both sides of each 33 year mortality cluster that was based on the home range size of white-tailed deer.

There were no data available on the home range size of white-tailed deer in Kootenay National Park or nearby areas with a similar ecosystem (Personal communication, Alan Dibb, Parks Canada; Trevor Kinley, Sylvan Consulting Ltd. Invermere, British Columbia). However, the majority of the white-tailed deer in Kootenay National Park are considered migratory; most of the individuals appear to leave the Kootenay Valley in winter, or alternatively, spend most of the winter in the Kootenay Valley away from the highway (Personal Communication, Alan Dibb, Parks Canada). This hypothesis appears to be supported by the seasonal distribution of the road mortality data for white-tailed deer (Figure 16). See Appendix M and N for seasonal distribution of road mortality for other species as well as the number of reported road mortalities per species per year.

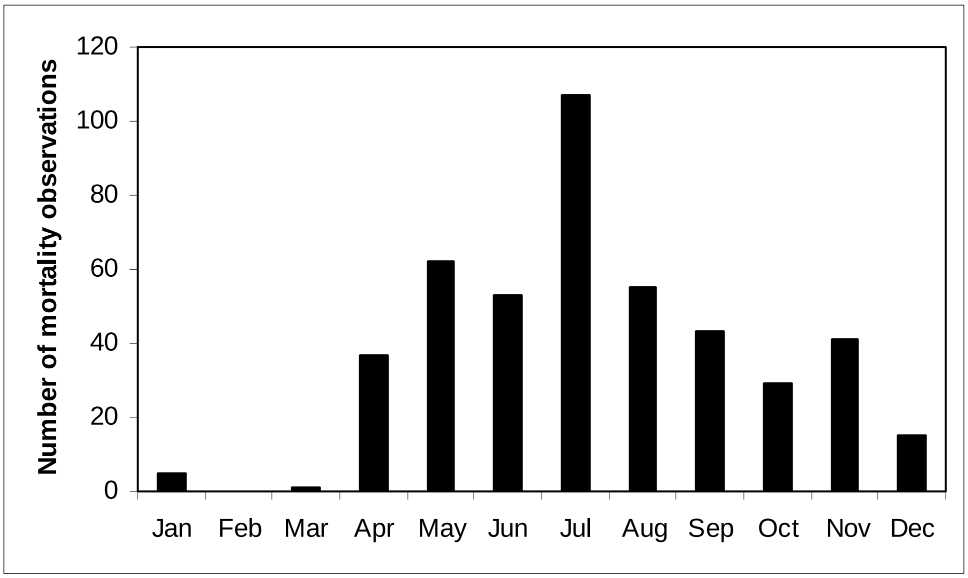

Figure 16. Seasonal distribution of road mortality observations of white tailed deer in Kootenay and Banff road sections (1975- 2007), observed within 100 m Hwy 93S.

For these reasons the researchers identified summer home range size estimates for white-tailed deer from other studies in other areas in the Northern Rocky Mountains, west of the continental divide (Table 5). The researchers assumed a summer home range of 70 ha (diameter home range is 944 m). Therefore the researchers applied a buffer zone of 1 km on both sides of each 33 year mortality cluster with ≥20% white-tailed deer road mortality. Even though the length of the 1 km long buffer zone was based on the summer home range size of white-tailed deer, the researchers also applied this buffer zone at 33 year mortality clusters with ≥20% elk or moose road mortality. These buffer zones reduced the likelihood of fence end runs by white-tailed deer (and other species), unless the distribution of white-tailed deer (and other species) in the area changes substantially as a result of the presence of a wildlife fence. Yet if such potential large scale changes were taken into account, very little of the road would remain unfenced. The latter would be in direct conflict with the directions given by Parks Canada for this project (see Chapter 1). Other large ungulates in Kootenay National Park, e.g. mule deer, elk, and moose, have much larger home ranges (Doerr 1983, Mackie et al. 1998, Anderson et al. 2005, Poole et al. 2007). However, mule deer appear to have substantially declined in numbers in Kootenay National Park over the last two decades (Personal Communication, Alan Dibb, Parks Canada), applying a buffer zone for elk would likely result in continuous fencing throughout Banff and Kootenay National Park (this would contrast with the directions given by Parks Canada for this project, see Chapter 1), and moose are unlikely to be attracted to the grass-herb vegetation in the right-of-way to begin with.

Table 5. Home range size estimates for white-tailed deer in the Northern Rocky Mountains, west of the continental divide.

Location	Home range size (ha)	Qualifications	Source
Swan Valley, MT, USA	<80	Summer and winter home range, but individuals may migrate 5-72 km between seasonal ranges	Mundinger (1981)
Swan Valley, MT, USA	70.5	Adult females, single summer home range	Leach & Edge (1994)
Swan Valley, MT, USA	91	Juvenile females, single summer home range	Leach & Edge (1994)
Coniferous forests, MT, USA	60-70	Migratory females, summer home range	Review in Mackie et al. (1998)

In addition to buffer zones, the researchers applied a minimum size for a gap of mitigation measures designed to keep wildlife away from the road. The minimum distance between where a fence, or other barrier type ends and another barrier starts was set at 1 km. However, if mule deer, elk, or moose represented >20% of the wildlife road mortality in one of the two 33 year mortality clusters on either side of a gap, the minimum gap size was set at 2 km.

The combination of 33 year mortality clusters, buffer zones and minimum gap sizes resulted in five “mitigation zones” for the road sections in Kootenay and Banff National Park (Table 6, Figure 17, Appendix B, C). The southern end of the 2.0-48.3 zone (point 2.0 km) coincided with the hot spring pools. While bighorn sheep mortality has occurred further south, the posted speed limit is relatively low already, and the implementation of e.g. wildlife fencing or animal detection systems would be problematic because of the parking area for the hot springs, side walks and heavy pedestrian traffic.

The 33 year mortality clusters for the road sections in and around Radium Hot Springs related to bighorn sheep only (Table 6, Figure 17, Appendix D). Here there were two 33 year mortality clusters, one on “Mile Hill”, just south of Radium Hot Springs, and one on Highway 95, just north of the junction of highway 93S and 95 in Radium Hot Springs (Appendix D). The southern end of the mitigation zone on Mile Hill coincides with an access road on top of the hill, and the northern end of this mitigation zone coincides with the edge of the village of Radium Hot Springs. The researchers suggest wildlife fencing as the preferred mitigation measure to reduce bighorn sheep collisions at this location (see also Chapter 7). Wildlife fencing further north, in the village of Radium Hot Springs would be problematic because of side roads, side walks, pedestrian traffic, and public opinion regarding high fences that would bisect the village. The mitigation zone just north of the junction with Highway 93 and 95 is inside the village and has relatively low posted speed limits (60 km/h, see Appendix A). For these reasons the researchers suggest an animal detection system at this location (see also chapter 7). Despite the fact that there is a side walk and pedestrian traffic north of the Jct in Radium Hot Springs, an animal detection system could work if it is a beak-the-beam system that is positioned a few meters from the side walk, on the slopes. Since animal detection systems do not restrict animal movements, the buffer zone is restricted to 100 m on each side of the 33 year mortality cluster.

Table 6. Begin and end point, and length of the mitigation zones.

Road section	Begin and end point mitigation zones (km*)	Length mitigation zones (km)
Kootenay	2.0 – 48.3	46.3
Kootenay	52.1 – 56.6	4.5
Kootenay	60.5 – 62.9	2.4
Kootenay	69.9 – 75.8	5.9
Kootenay / Banff	91.1 – 8.9	3.0
Radium Hot Springs South	0.6 – 3.4	2.8
Radium Hot Springs North	0.1 – 0.7	0.6

*** = the start and end points are actual points rather than 100 m road units.**

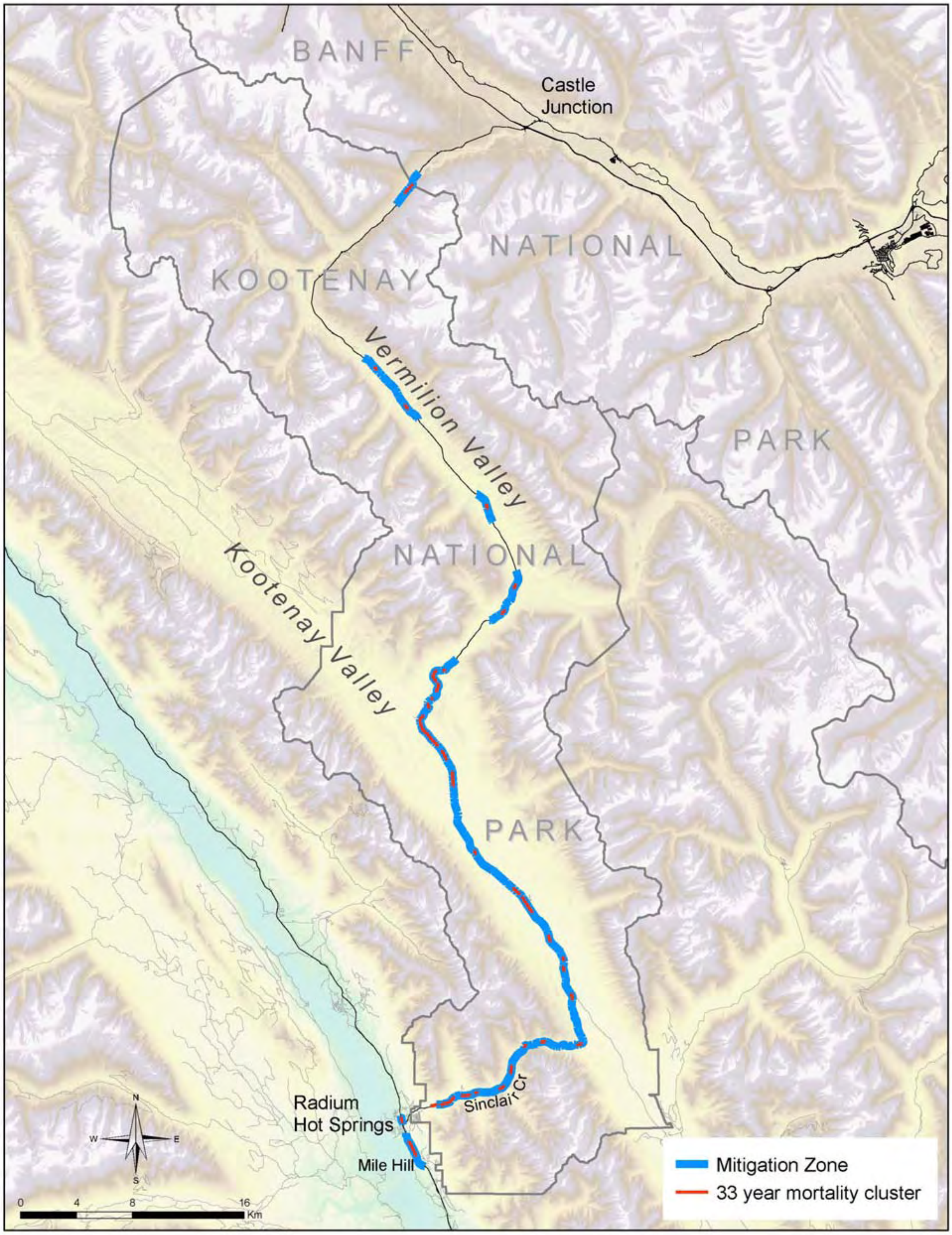

Figure 17. Mitigation zones and road mortality clusters based on 33 year road mortality data, observed within 100 m of Hwy 93S/95.

4. PRIORITIZATION OF WILDLIFE MORTALITY ROAD SECTIONS

4.1 10 Year Mortality Clusters

The highway mitigation plan for the study area may not be carried out in its entirety at the same time. Therefore Parks Canada requested that the road sections that are recommended for highway mitigation measures are prioritized (see Chapter 1).

The 33 year mortality clusters and mitigation zones were identified based on 33 years of wildlife road mortality data (1975 through 2007). The prioritization procedure however, was based on the past 10 years only (1998 through 2007). This relatively short time period was based on the following considerations:

- Using a relatively short and recent time period allows for the identification of road sections where mitigation measures have the greatest return on short term in terms of human safety, reduced wildlife mortality, while having maintained at least a certain degree of habitat connectivity.
- A ten year period appears to be a good balance between having sufficient and relatively robust data and still have the data relate as much as possible to the current situation, and the situation in the immediate future.
- The ten year period (1998 through 2007) represents a time period with a relatively stable population size for two of the most commonly killed species; white-tailed deer and elk (Personal Communication, Alan Dibb, Parks Canada). In this time period, the elk population was relatively low and the white-tailed deer population relatively high.

The majority of reported mortalities of focal species within 100 m of the road in the Kootenay-Banff study area section from 1998 to 2007 were of ungulate species (Figure 18), with a wider variety of species each making up less than 5% of the observations (Table 7).

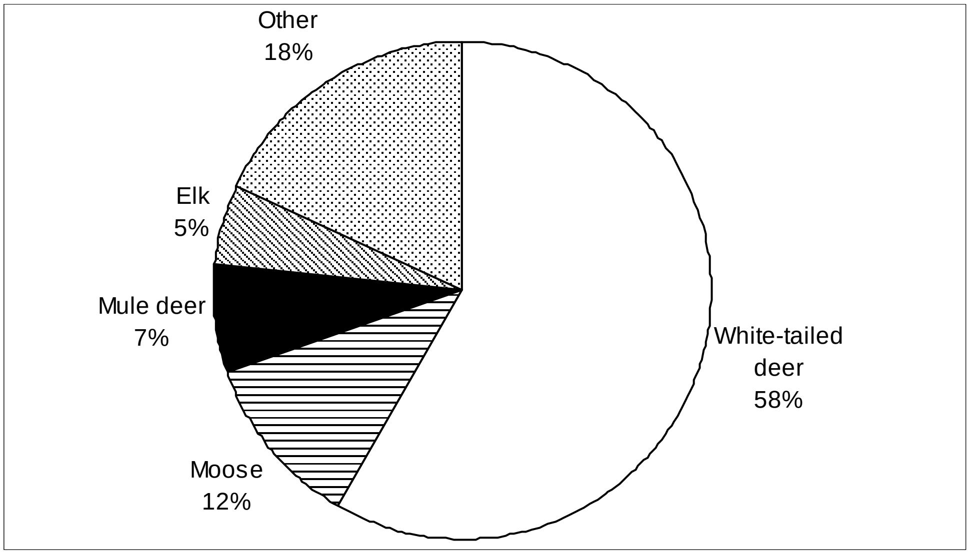

Figure 18. Relative abundance of reported road killed species (species listed in table 2 only) on the road sections in Kootenay and Banff National Park (1998 through 2007), found within 100m of Hwy 93S (N total = 378)

Table 7. Number and relative abundance (%) of road killed species (species listed in Table 2 only) included in the "other" category in Figure 18. The data relate to road killed wildlife in Kootenay and Banff National Park (1998 through 2007), found within 100m of Hwy 93S

Other species	Number of Mortalities	Percentage
Coyote	18	4.76
Black bear	14	3.70
Deer	14	3.70
Bighorn sheep	14	3.70
Wolf	4	1.06
Mountain goat	2	0.53
Grizzly bear	1	0.26
Canada lynx	1	0.26
Total	68	17.99

The researchers used a prioritization procedure that was similar to the procedure used to identify 33 year mortality clusters (section 3.2).

The procedure for the road sections in Kootenay and Banff National Park was as follows:

- Of the wildlife road mortality data selected for the identification of 33 year mortality clusters (see paragraph 3.2) the researchers selected only the observations from 1998 through 2007.
- The total number of wildlife road mortality observations was calculated for each 100 m road unit. No distinction was made between the different species; all species (see Table 2) were weighed equally. The number of observations in each 100 m long road unit reflects the total number of wildlife road mortality observations, regardless of the focal species, in or adjacent (maximum distance from road is 100 m) to that 100 m long road unit.
- For each 100 m long road unit, a "wildlife road mortality value" was calculated by taking the sum of the unit concerned and its two neighboring units. For example, if adjacent 100 m long units had the following number of observations: 0, 1, 3, 2, 4, 2, 0, the "wildlife road mortality value" for these 100 m units was (?+1), 4, 6, 9, 8, 6, (2+?) (see also Appendix B and C (Kootenay and Banff sections). Thus the "wildlife road mortality value" for each 100 m road unit was related to the number of mortality observations in a 0.3 km road length section. This procedure recognized that an observation may have actually occurred in the neighboring 100 m road unit (potential spatial errors or spatial imprecision of observers) and it provided for a variable with values with a smoother transition between adjacent 100 m road units as the "wildlife road mortality value" for each 100 m unit was also influenced by its two neighboring units.
- Six categories of the "wildlife road mortality values" were distinguished for the 100 m road units. The cut-off levels for these categories were determined using the following procedure:
    - 100 m units with a "0" wildlife road mortality value were classified as "absent" (Table 8).
    - The remaining 100 m units had a wildlife road mortality value of 1 or greater and the researchers calculated the 20, 40, 60 and 80 percentiles and classified each of the 100 m units as one of the following: "very low" (>0-20%), "low" (20-40%), "medium" (40-60%), "high" (60-80%), and "very high" (80-100%) (Table 8).

The procedure for the road sections in and around Radium Hot Springs was as follows:

- Of the wildlife road mortality data selected for the identification of 33 year mortality clusters (see paragraph 3.2), the researchers selected only bighorn sheep observations from 1998 through 2007.
- The number of observations in each 100 m long road unit reflects the total number of bighorn speed road mortality observations in or adjacent (maximum distance from road is 100 m) to that 100 m long road unit.

- For each 100 m long road unit, a “bighorn sheep road mortality value” was calculated by taking the sum of the unit concerned and its two neighboring units (see procedure for road sections in Kootenay and Banff National Park and see Appendix D (Radium Hot Springs road sections).
- Using a similar procedure as described for the road sections in Kootenay and Banff National park, six categories of the “bighorn sheep road mortality value” were distinguished (Table 8).

Table 8. Cutoff levels of “wildlife road mortality values” for the mitigation zones in Kootenay and Banff National park, and the “bighorn sheep road mortality values” for the mitigation zones in and around Radium Hot Springs.

Data source	Absent	Very Low	Low	Medium	High	Very high
Kootenay/Banff	0	1	1	1	2	3-8
Radium	0	1	1	2-3	4 – 7	8- 18

The researchers identified “10 year road mortality clusters” by marking all 100 m road units categorized as “very high” (Figure 19, Appendix B, C and D). If a 100 m road unit marked as “very high” had adjacent units that were classified as “high”, these units were marked as well (Appendix B, C and D). The “marking” on either side of a 100 m road unit classified as “very high” stopped when a 100 m road unit occurred that was classified as “medium” or lower. If a 100 m road unit classified as “high” was not adjacent to a 100 m road unit classified as “very high” it was not included in any of the 10 year mortality clusters. Thus, “10 year road mortality clusters” consisted of the “worst 20%” of all 100 m road units (excluding the 100 m road units that were classified as “absent”) and the adjacent 100 m units, as long as these fell within the “worst 40%” (excluding the 100 m road units that were classified as “absent”) (Appendix B, C and D). Note that the 10 year mortality clusters were based on a 10 year long time period (1998 through 2007). The location of the 10 year mortality clusters is not as robust as the 33 year mortality clusters, and is much less influenced by dynamics in the ecosystem that may occur within the life span of the mitigation measures one may choose to implement.

For each 10 year mortality cluster in Kootenay and Banff National Park, the researchers calculated the percentage of each species based on the number of wildlife road mortality observations in the cluster (Appendix F). These data showed the researchers what species wildlife-vehicle collision reduction measures should be designed for, for each 10 year mortality cluster. The wildlife observations for the road sections in and around Radium Hot Springs related to bighorn sheep only (see section 3.2).

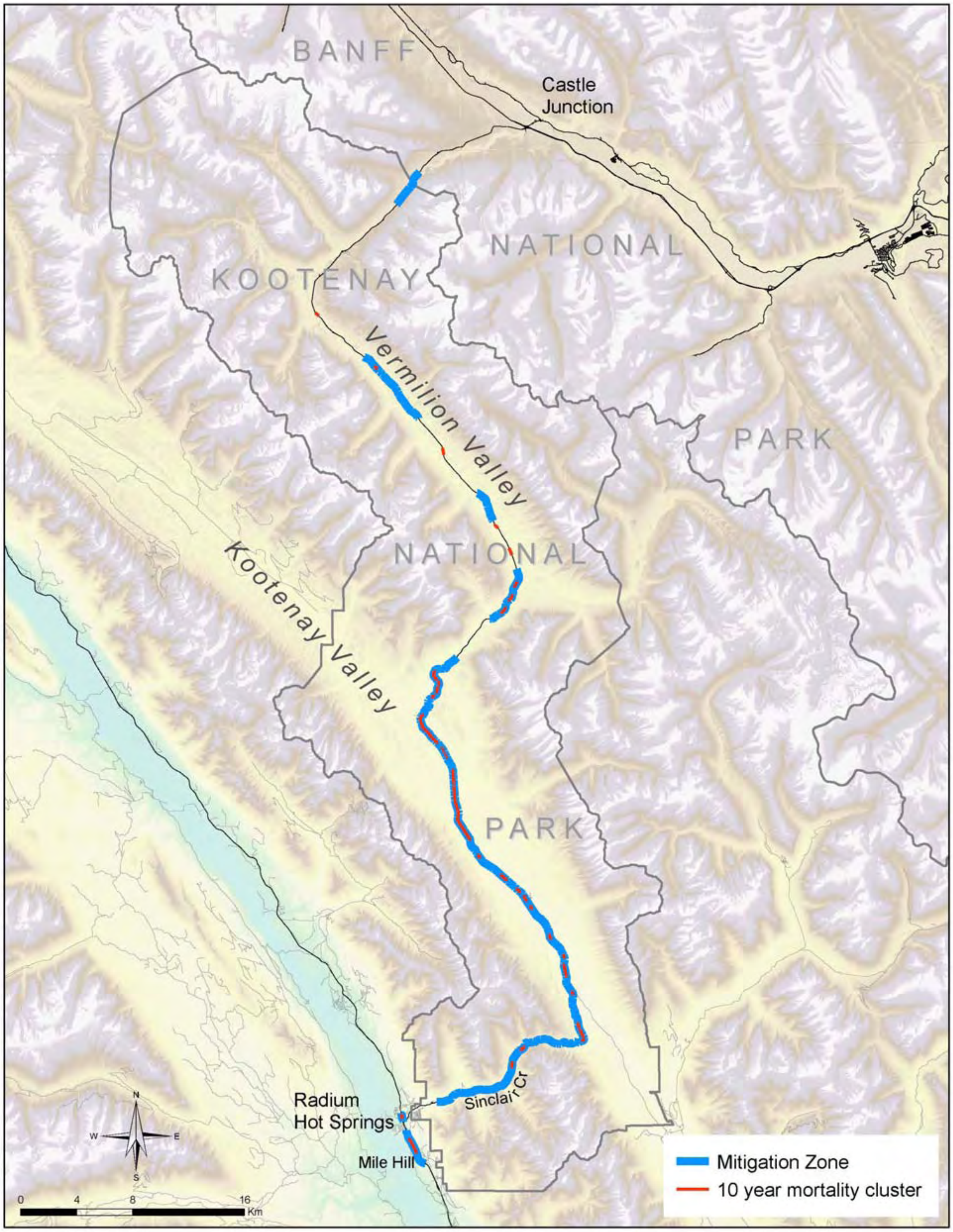

Figure 19. Mitigation zones and road mortality clusters based on 10 year road mortality data, observed within 100 m of Hwy 93S/95.

4.2 Prioritization, Level 1

Not all of the 10 year mortality clusters fell in the mitigation zones described in section 3.3. The 10 year mortality clusters located outside of the mitigation zones were identified but not prioritized (Table 9). Mitigation measures for 10 year mortality clusters within mitigation zones are based on a 33 year long time period with the associated dynamics in the ecosystem ("long term management"). Mitigation measures for 10 year mortality clusters outside the mitigation zones would be based on addressing relatively recent problems that may or may not be classified as a problem given more time ("short term management"). No 10 year mortality cluster fell only partially within a mitigation zone – all 10 year mortality clusters were either fully inside or fully outside the mitigation zones.

Table 9. 10 year mortality clusters outside the mitigation zones for the road sections in Kootenay and Banff National Park and the road sections in and around Radium Hot Springs. These mortality clusters were not ranked based on their severity.

Road Section	Begin and end point 10 year mortality cluster (km*)
Kootenay/Banff	57.7 – 58.2
Kootenay/Banff	59.9 – 60.2
Kootenay/Banff	66.6 – 67.1
Kootenay/Banff	80.3 – 80.6

*** = the start and end points are actual points rather than 100 m road units.**

For each 10 year mortality cluster that fell in one of the mitigation zones, the researchers summed the wildlife road mortality values (Kootenay/Banff) or the bighorn road mortality values (Radium Hot Springs). This number was divided by the number of 100 m road units of the 10 year mortality cluster concerned, standardizing a measure for the number of road killed wildlife or bighorn sheep. The resulting "ranking value" allowed for a direct comparison of the severity of the 10 year mortality clusters (Table 10 and 11). The higher the ranking value, the greater the number of road killed wildlife or bighorn sheep in a cluster. This ranking process was carried out separately for the road sections in Kootenay and Banff National Park, and the road sections in and around Radium Hot Springs ("level 1").

Table 10. 10 year mortality clusters and their ranking in the mitigation zones for the road sections in Kootenay and Banff National Park.

Road Section	Begin and end point 10 year mortality clusters (km*)	Ranking value		Road Section	Begin and end point 10 year mortality clusters (km*)	Ranking value
Kootenay	26.3 - 26.8	5.40		Kootenay	14.9 - 15.2	2.67
Kootenay	40.0 - 42.6	4.73		Kootenay	38.7 - 39.6	2.67
Kootenay	36.7 - 37.8	4.36		Kootenay	45.6 - 46.4	2.63
Kootenay	32.4 - 36.6	3.71		Kootenay	18.5 - 18.8	2.33
Kootenay	27.1 - 27.5	3.50		Kootenay	21.3 - 21.6	2.33
Kootenay	25.6 - 25.9	3.33		Kootenay	28.4 – 29.0	2.33
Kootenay	23.0 - 23.4	3.25		Kootenay	30.9 - 31.2	2.33
Kootenay	44.6 – 45.1	3.20		Kootenay	45.2 - 45.5	2.33
Kootenay	44.1 - 44.4	3.00		Kootenay	54.1 - 54.7	2.33
Kootenay	55.2 - 55.7	3.00		Kootenay	10.0 - 10.4	2.25
Kootenay	74.5 - 74.8	3.00		Kootenay	16.0 - 16.4	2.25
Kootenay	53.0 - 53.6	2.83		Kootenay	15.3 – 15.9	2.17
Kootenay	19.9 - 20.9	2.70		Kootenay	8.5 – 9.0	1.00

*** = the start and end points are actual points rather than 100 m road units.**

Table 11. 10 year mortality clusters and their ranking in the mitigation zones for the road sections in and around Radium Hot Springs.

Road Section	Begin and end point 10 year mortality cluster (km*)	Ranking value
Radium Hot Springs South	1.2 - 2.4	10.00
Radium Hot Springs North	0.3 – 0.6	7.33

*** = the start and end points are actual points rather than 100 m road units.**

4.3 Prioritization, Level 2

The implementation of mitigation measures is likely to be associated with road reconstruction projects. Such road reconstruction projects may not be conducted for the entire road at one time. Road reconstruction projects typically deal with continuous road sections, rather than leaving relatively short gaps of "old road" in between sections of reconstructed road. For these reasons, Parks Canada requested the prioritization of mitigation measures within four subsections in Kootenay and Banff National Park (see Chapter 1):

- Sinclair Creek and Canyon: southern border Kootenay National Park to Sinclair Summit/Olive Lake (0.0-11.9 km*)
- Kootenay Valley: Sinclair Summit/Olive Lake to Hector Gorge Viewpoint (11.9 – 46.3 km*)
- Vermilion Valley: Hector Gorge Viewpoint to Numa Falls site (46.3 – 78.7 km*)
- Vermilion Pass - Castle Junction: Numa Falls site to Castle Junction (78.7 – 0 km*)

  * = The start and end points are actual points rather than 100 m road units.

The researchers used the exact same ranking values as in section 4.2 (Table 10). However, their "level 2" prioritization depended on their relative ranking in the subsection they were located in (Table 12, 13 and 14). The Vermilion Pass - Castle Junction subsection had no 10 year mortality clusters. Note that short sections of fencing may cause animals to simply cross the road where the fence ends, especially species that may be attracted to the right-of-way vegetation (e.g. white-tailed deer, elk).

Table 12. 10 year mortality clusters and their ranking in the mitigation zones for the subsection Sinclair Creek and Canyon in Kootenay National Park.

Begin and end point 10 year mortality clusters (km*)	Ranking value
10.0 - 10.4	2.25
8.5 – 9.0	1.00

*** = the start and end points are actual points rather than 100 m road units.**

Table 13. 10 year mortality clusters and their ranking in the mitigation zones for the subsection Kootenay Valley in Kootenay National Park.

Begin and end point 10 year mortality cluster (km*)	Ranking value		Begin and end point 10 year mortality cluster (km*)	Ranking value
26.3 - 26.8	5.40		14.9 - 15.2	2.67
40.0 - 42.6	4.73		38.7 - 39.6	2.67
36.7 - 37.8	4.36		45.6 - 46.4 *extends into Vermilion subsection	2.63
32.4 - 36.6	3.71		18.5 - 18.8	2.33
27.1 - 27.5	3.50		21.3 - 21.6	2.33
25.6 - 25.9	3.33		28.4 – 29.0	2.33
23.0 - 23.4	3.25		30.9 - 31.2	2.33
44.6 – 45.1	3.20		45.2 - 45.5	2.33
44.1-44.4	3.00		16.0 - 16.4	2.25
19.9 - 20.9	2.70		15.3 - 15.9	2.17

***= the start and end points are actual points rather than 100 m road units.**

Table 14. 10 year mortality clusters and their ranking in the mitigation zones for the subsection Vermilion Valley in Kootenay National Park.

Begin and end point 10 year mortality cluster (km*)	Ranking value
55.2 - 55.7	3.00
74.5 - 74.8	3.00
53.0 - 53.6	2.83
45.6 - 46.4* extends into Kootenay subsection	2.63
54.1 - 54.7	2.33

*** = the start and end points are actual points rather than 100 m road units.**

5. LOCATION OF SAFE CROSSING OPPORTUNITIES FOR WILDLIFE

5.1 Safe Crossing Opportunities

Chapter 3 provided a rationale for the identification of road sections that require mitigation to reduce the number of wildlife-vehicle collisions, based on a 33 year data set. Chapter 4 described what road sections have priority over others, based on the abundance of wildlife road kill over the last 10 years. Wildlife fencing is one of the most effective mitigation measures for reducing wildlife road mortality (Huijser & Paul 2008), and the researchers suggest primarily wildlife fencing for the mitigation zones in the study area (see Chapter 7). However, wildlife fencing increases the barrier effect of roads, often resulting in an almost impermeable barrier for the target species. Wildlife fencing is a barrier to different types of wildlife movements. Wildlife fencing blocks or reduces:

- Movements within an individuals' home range if its home range is located on both sides of a road.
- Seasonal migration (e.g. migratory deer or elk)
- Long distance dispersal (colonize or re-colonize far away areas, or increase the population viability of small and isolated populations)

Wildlife fencing, and other measures that result in a substantial or even impermeable barrier for wildlife, should typically be accompanied with safe crossing opportunities. Safe crossing opportunities may include e.g. wildlife underpasses and overpasses, or animal detection systems.

5.2 Wildlife Observations On and Near Roads in the Mitigation Zones

The researchers combined the following data sets of wildlife observations on and near roads in the mitigation zones:

- All reported or possible wildlife mortalities in the study area from 1975 through 2007. These data included, but were not restricted to road mortality. These data were provided by Parks Canada.
- All reported observations of wildlife (alive) in the study area from 1975 through 2007. These data were provided by Parks Canada

All data were plotted in a GIS (ESRI ArcGIS 9.2). The researchers measured the shortest possible distance from each observation location to the road and only selected those observations that were within 100 m of the road. This procedure related to all road sections in the study area (Figure 7 and 8). The researchers did not exclude any species from this process.

All selected wildlife observations (dead and alive) were "snapped" to the nearest 100 m long road unit using a GIS (ESRI ArcGIS 9.2). The number of wildlife observations was summed for each 100 m unit (see Appendix B, C, D (all road sections)). No distinction was made between the different species; all species were weighed equally. As the purpose of the analyses was to calculate where safe crossing opportunities within mitigation zones should be located, the researchers selected the observations that fell in the mitigation zones (Table 6, Figure 17). Wildlife observations that fell outside of the mitigation zones were not included in the analyses.

The selected wildlife observations in the mitigation zones included many different species, but ungulates and black bears represented most of the observations (Figure 20). Other species, each making up less than 5% of the observations, included a wide variety of species including birds and small or medium sized mammals (Table 15). The researchers recognized that not all species are likely to suffer from road mortality or to benefit from safe crossing opportunities. However, the researchers did not want to make a subjective decision on excluding certain species, not even birds (e.g. gaps in fence or vegetation that encourages birds to fly high when crossing a road) from a procedure that identified areas where safe crossing opportunities for wildlife may have to be provided for when the location, type and dimensions of such crossing opportunities have not yet been decided on. In the mitigation zones in and around Radium Hot Springs, there were 55 observations of bighorn sheep, 5 for mule deer and 1 for elk.

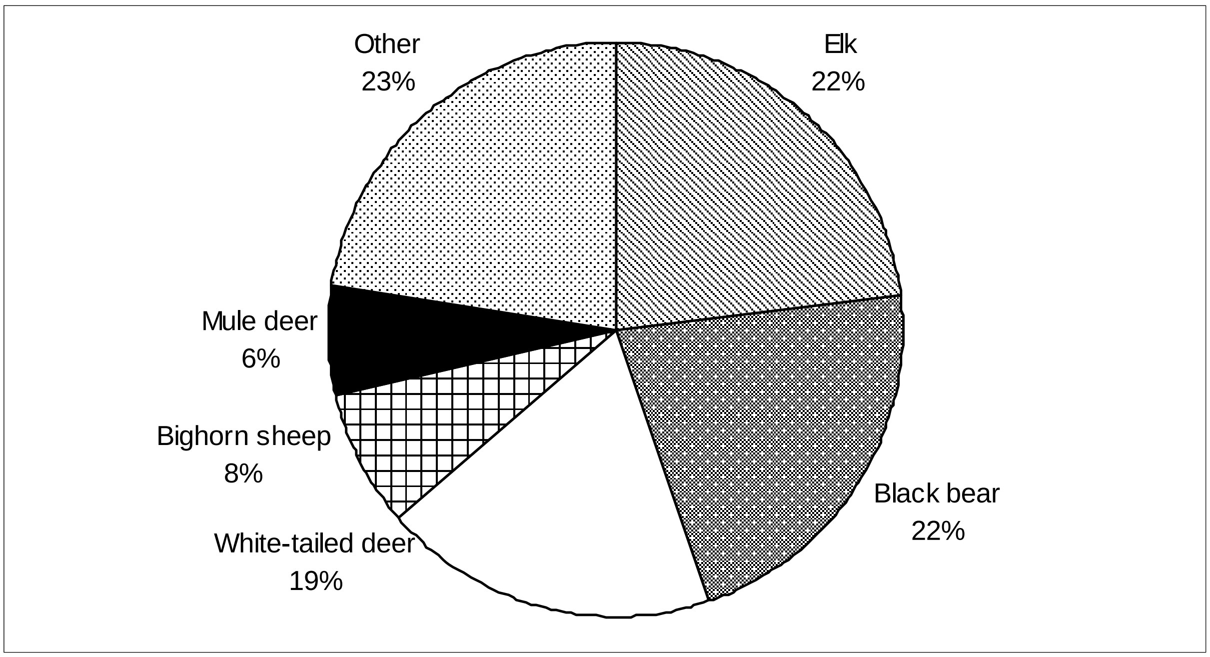

Figure 20. Relative abundance of reported species (all reported species), dead or alive, in the mitigation zones (see Table 6) on the road sections in Kootenay and Banff National Park (1975 through 2007), found within 100m of Hwy 93S (N total = 2,944)

Table 15. Number and relative abundance (%) of "other" reported species (all reported species) (Figure 20), dead or alive, in the mitigation zones (see Table 6) on the road sections in Kootenay and Banff National Park (1975 through 2007), found within 100m of Hwy 93S

Species	Number of observations	Percentage
Moose	160	4.60
Coyote	138	3.97
Wolf	115	3.31
Mountain goat	58	1.67
Deer	37	1.06
Bird	26	0.75
Small rodents	25	0.72
Pine marten	20	0.58
Porcupine	16	0.46
Snowshoe hare	14	0.40
Grizzly bear	11	0.32
Herpetofauna	10	0.29
Bear	7	0.20
Skunk	6	0.17
Cougar	5	0.14
Beaver	3	0.09
Hoary marmot	3	0.09
Canada lynx	3	0.09
Wolverine	3	0.09
Badger	2	0.06
Unknown	2	0.06
Bobcat	1	0.03
Red fox	1	0.03

5.3 Wildlife Observation Clusters in the Mitigation Zones

Road sections with a concentration of wildlife observations (“wildlife observation clusters”) were identified separately for the road sections in Kootenay and Banff National Park and the road sections in and around Radium Hot Springs.

The researchers used the following procedure to identify wildlife observation clusters within the mitigation zones.

The procedure for the road sections in Kootenay and Banff National Park was as follows:

- For each 100 m long road unit, a “wildlife observation value” was calculated by taking the sum of the unit concerned and its two neighboring units. For example, if adjacent 100 m long units had the following number of observations: 0, 1, 3, 2, 4, 2, 0, the “wildlife observation value” for these 100 m units was (?+1), 4, 6, 9, 8, 6, (2+?) (see also Appendix B and C (Kootenay and Banff sections). Thus the “wildlife observation value” for each 100 m road unit was related to the number of wildlife observations in a 0.3 km road length section. This procedure recognized that an observation may have actually occurred in the neighboring 100 m road unit (potential spatial errors or spatial imprecision of observers) and it provided for a variable with values with a smoother transition between adjacent 100 m road units as the “wildlife observation value” for each 100 m unit was also influenced by its two neighboring units.
- Six categories of the “wildlife observation values” were distinguished for the 100 m road units. The cut-off levels for these categories were determined using the following procedure:
    - 100 m units with a “0” wildlife observation value were classified as “absent” (Table 16).
    - The remaining 100 m units had a wildlife observation value of 1 or greater and the researchers calculated the 20, 40, 60 and 80 percentiles and classified each of the 100 m units as one of the following: “very low” (>0-20%), “low” (20-40%), “medium” (40-60%), “high” (60-80%), and “very high” (80-100%) (Table 16).

The procedure for the road sections in and around Radium Hot Springs was conducted separately (Appendix D), but was otherwise identical to that for the road sections in Kootenay and Banff National Park.

Table 16. Cutoff levels of “wildlife observation values” for the mitigation zones in Kootenay and Banff National Park, and for the mitigation zones in and around Radium Hot Springs.

Data source	Absent	Very Low	Low	Medium	High	Very high
Kootenay/Banff	0	1-6	7-10	11-15	16 - 25	26 – 77
Radium	0	1	2 - 4	5 - 7	8 - 9	10 – 18

The researchers identified “wildlife observation clusters” by marking all 100 m road units categorized as “very high” (Appendix B, C and D). If a 100 m road unit marked as “very high” had adjacent units that were classified as “high”, these units were marked as well (Appendix B, C and D). The “marking” on either side of a 100 m road unit classified as “very high” stopped when a 100 m road unit occurred that was classified as “medium” or lower. If a 100 m road unit classified as “high” was not adjacent to a 100 m road unit classified as “very high” it was not included in any of the wildlife observation clusters. Thus, within the mitigation zones, “wildlife observation clusters” consisted of the “highest 20% wildlife observations” of all 100 m road units (excluding the 100 m road units that were classified as “absent”) and the adjacent 100 m units, as long as these fell within the “highest 40% wildlife observations” (excluding the 100 m road units that were classified as “absent”) (Appendix B, C and D). Note that the wildlife observation clusters were based on a 33 year long time period (1975 through 2007).

In addition to Appendix B, C and D, the locations of the wildlife observation clusters are shown in Figure 21. There was one bighorn sheep observation cluster (Radium Hot Springs South, km 1.2-2.1, 39 observations).

5.4 Prioritization of the Wildlife Observation Clusters in the Mitigation Zones

For each wildlife observation cluster that fell in the 46.3 km long mitigation zone in the Kootenay Valley (see Table 6), the researchers summed the wildlife observation values. This number was divided by the number of 100 m road units of the wildlife observation cluster concerned, standardizing a measure for the number of wildlife observations. The resulting “ranking value” allowed for a direct comparison of the importance of the wildlife observation clusters (Table 17). The higher the ranking value, the greater the number of wildlife observations in a cluster. This ranking process was not carried out for any of the other mitigation zones since the other mitigation zones had either no or only one wildlife observation cluster (Figure 21).

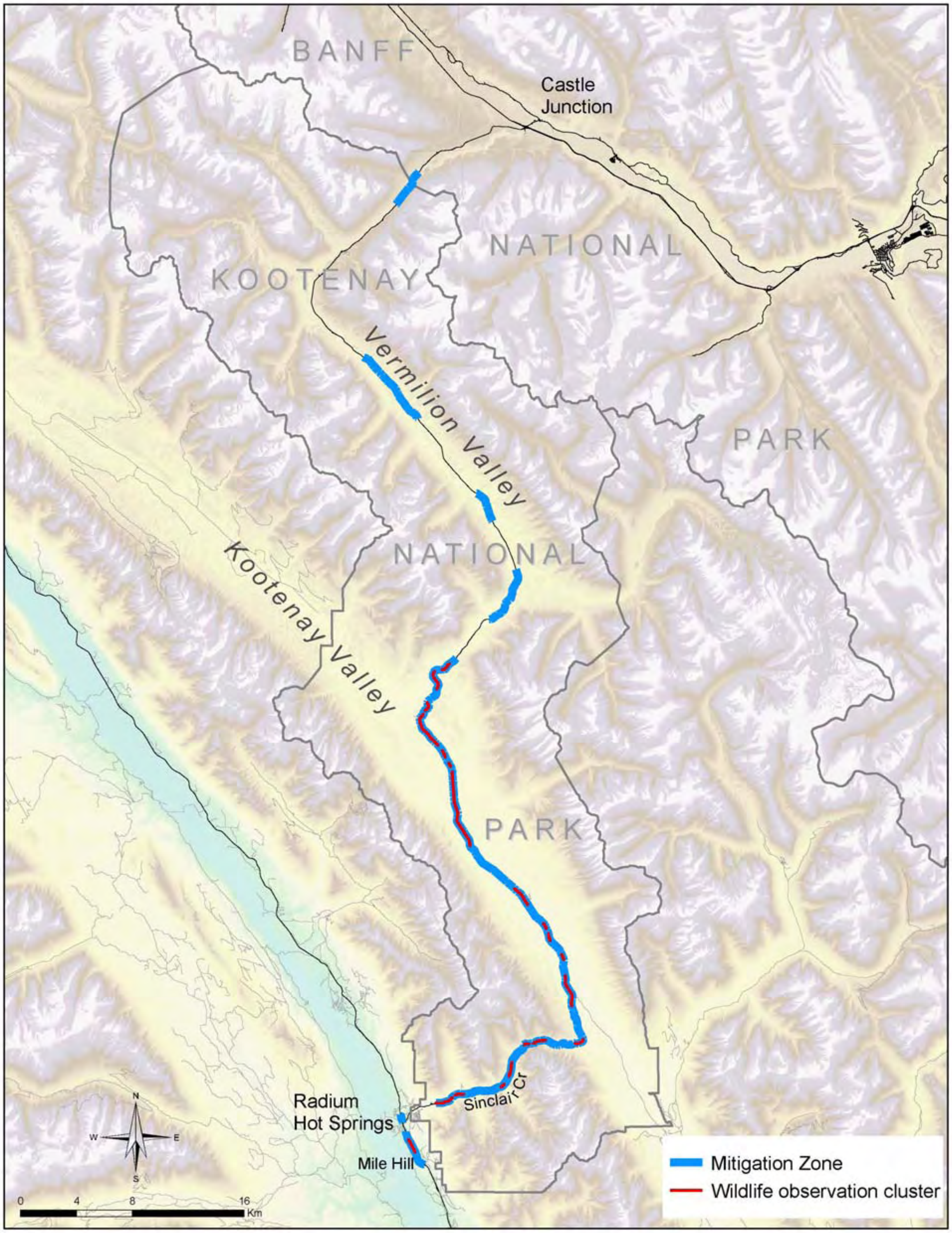

Figure 21. Mitigation zones and wildlife observation clusters based on 33 year observation data, dead and alive, observed within 100 m of Hwy 93S/95.

Table 17. Wildlife observation clusters and their ranking in the mitigation zones for the subsection Kootenay Valley in Kootenay National Park.

Road Section	Begin and end point wildlife observation clusters (km*)	Ranking value		Road Section	Begin and end point mitigation zones (km*)	Ranking value
Kootenay	26.1 - 27.6	38.4		Kootenay	2.0 - 2.2	28.5
Kootenay	23.0 - 23.5	36.6		Kootenay	14.5 - 15.2	27.3
Kootenay	32.1 - 36.0	36.5		Kootenay	38.1 - 38.4	26.7
Kootenay	47.0 - 47.7	36.3		Kootenay	38.9 - 39.4	26.6
Kootenay	2.3 - 3.3	36		Kootenay	19.2 - 19.6	26.3
Kootenay	46.1 - 46.4	35.3		Kootenay	10.6 - 11.0	25.3
Kootenay	41.5 - 42.7	34.4		Kootenay	19.8 - 20.3	24.4
Kootenay	7.0 - 7.3	34		Kootenay	23.9 - 24.3	22.5
Kootenay	43.0 - 43.7	33		Kootenay	21.3 - 21.7	22.3
Kootenay	11.3 - 12.2	32.6		Kootenay	3.6 - 4.2	21.3
Kootenay	39.9 - 41.4	31.4		Kootenay	45.0 - 45.9	20.8
Kootenay	36.1- 37.7	31.1		Kootenay	8.0 - 8.9	20.5
Kootenay	17.8 - 19.0	29.3				

5.5 Species Observed in Mitigation Zones

For each mitigation zone the researchers calculated the number and proportion of each species based on the underlying wildlife observations (Appendix G). These data showed the researchers what species safe crossing opportunities should be designed for, for each mitigation zone. The wildlife observations for the road sections in and around Radium Hot Springs related to bighorn sheep only.

5.6 Species Observed in Individual Wildlife Observation Clusters

For each wildlife observation cluster in Kootenay and Banff National Park, the researchers calculated the number and proportion of each species based on the underlying wildlife observations (Appendix H). These data showed the researchers what species safe crossing opportunities should be designed for, for each wildlife observation cluster. The wildlife observations for the road sections in and around Radium Hot Springs related to bighorn sheep only.

Appendix L provides an overview of observations per species per 100 m road unit in the mitigation zones in Kootenay and Banff National Park. The user of this report can use Appendix L to help locate areas along the road where specific species have been observed.

6. LOCAL EXPERIENCE AND KNOWLEDGE

In addition to examining the number and proportion of each species based on the underlying wildlife observations (Appendix G and H) for each wildlife observation cluster in Kootenay and Banff National Park, the researchers examined data occurring within mitigation zones from studies referred to in the Terms of Reference (Olsson 2002, Spiteri 2007, see Parks Canada 2007), and interviews with Alan Dibb, Wildlife Specialist, Lake Louise, and Yoho and Kootenay National Parks and Drew Sinclair, Highway Operations Supervisor, of Parks Canada (Appendix I, Figure 22 through 25)). The data were based on:

- Interview with Alan Dibb: Highlighted areas on topographic map of Hwy 93 from southern entrance of Kootenay National park to Vermilion Pass indicating where specific species were often observed;
- Interview with Drew Sinclair: Highlighted areas on topographic map of entire length of Highway 93 in Kootenay National Park indicating where specific species were often observed;
- Spatial data (UTMS) from Spiteri (2007): Locations of wildlife tracks in snow on specific transects within Kootenay Valley; and,
- Spatial data (UTMS) from Olsson 2002: locations of wolf tracks in snow crossing Highway 93 in Kootenay National Park (Olsson 2002).

Other datasets were made available by Parks Canada, but due to lack of data occurring along the highway or lack of specific location data, they were not further analyzed. Additional datasets of species other than bighorn sheep were not provided for the road sections in and around Radium Hot Springs.

These data showed the researchers whether additional species occurred or were perceived to occur within mitigation zones other than those species documented by the wildlife observation datasets (Appendix G and H). This information was used by the researchers in deciding where to locate safe crossing opportunities and what species the type and dimensions of these safe crossing opportunities should be designed for.

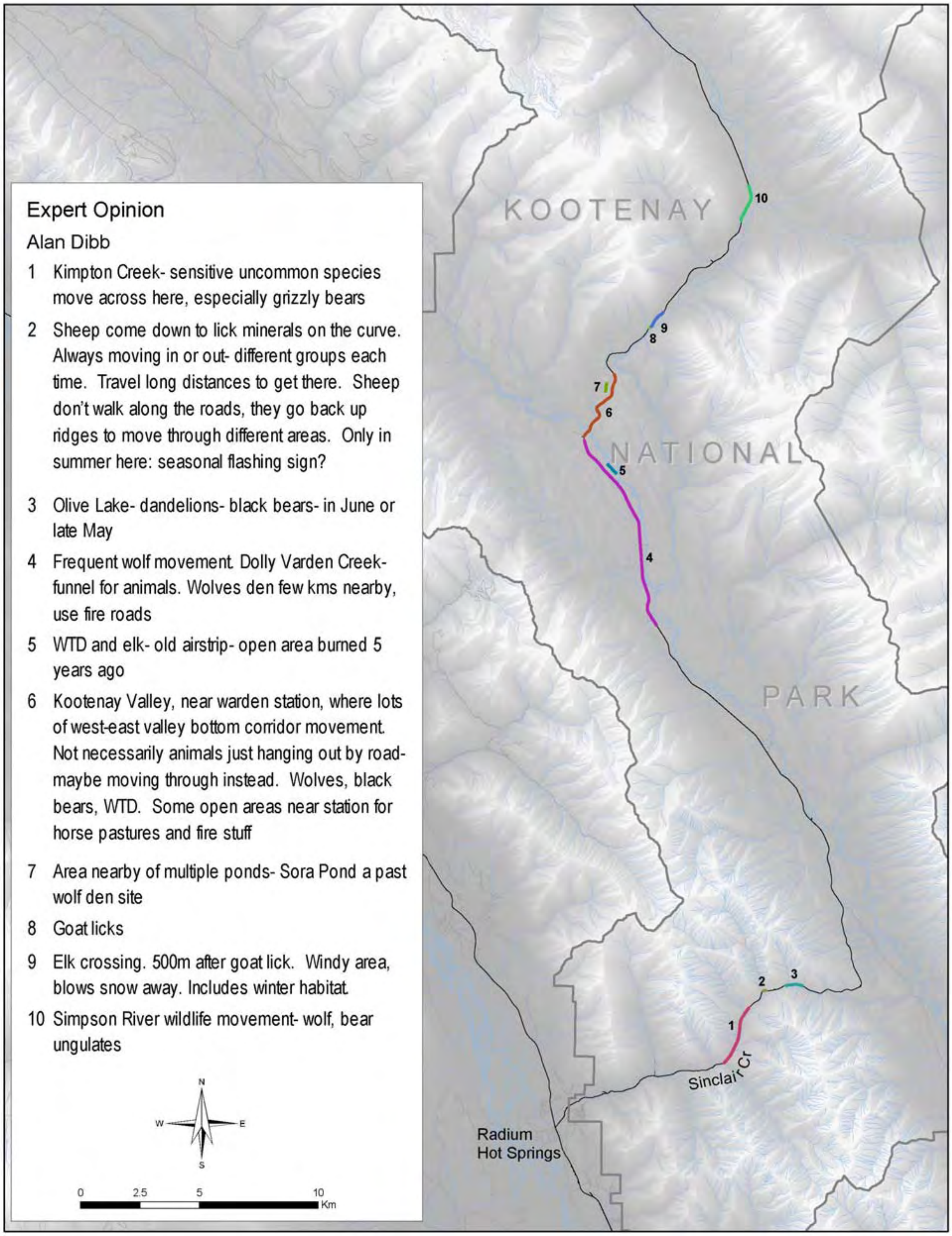

Figure 22. Wildlife observation data based on an interview with Alan Dibb, Parks Canada.

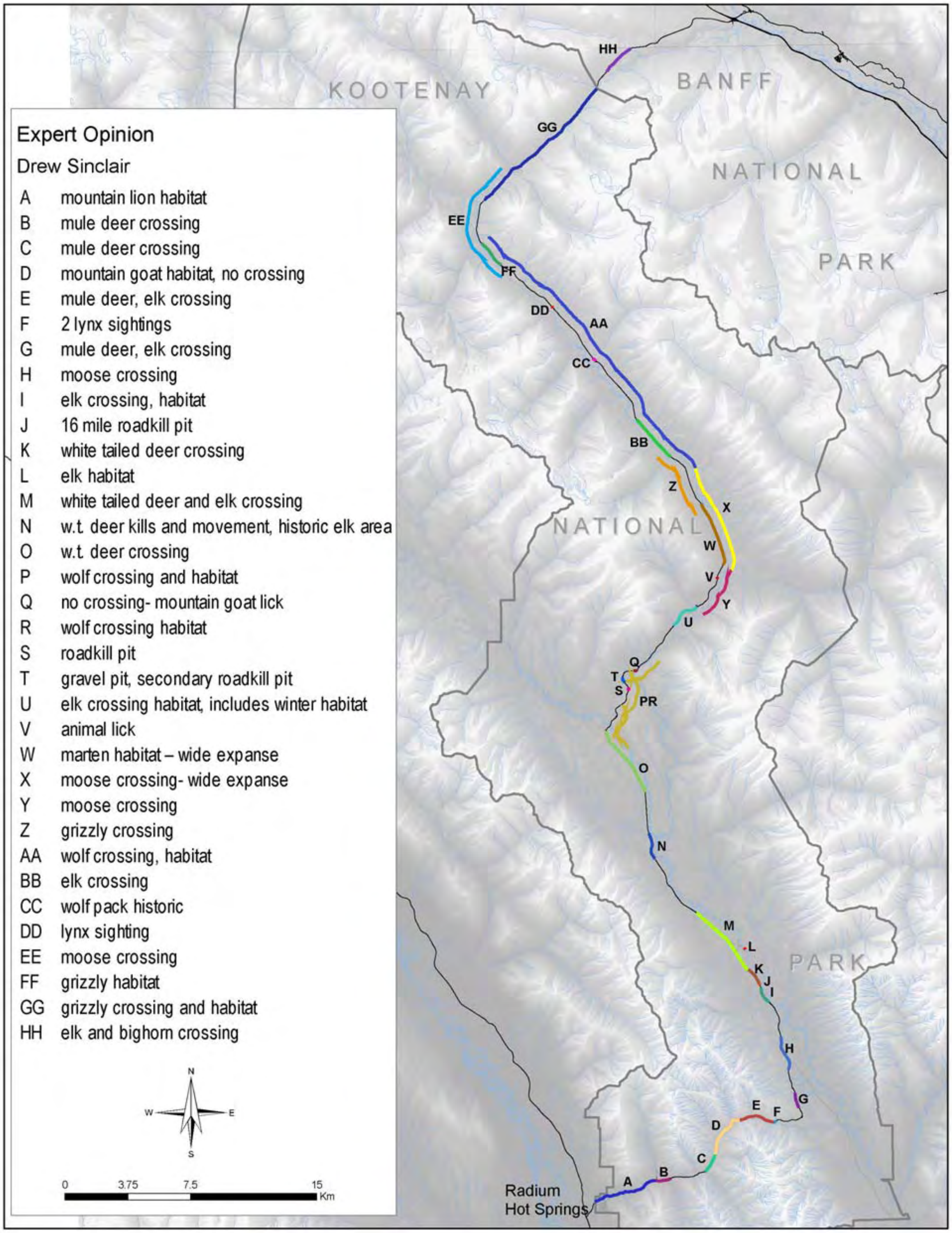

Figure 23. Wildlife observation data based on an interview with Drew Sinclair, Parks Canada.

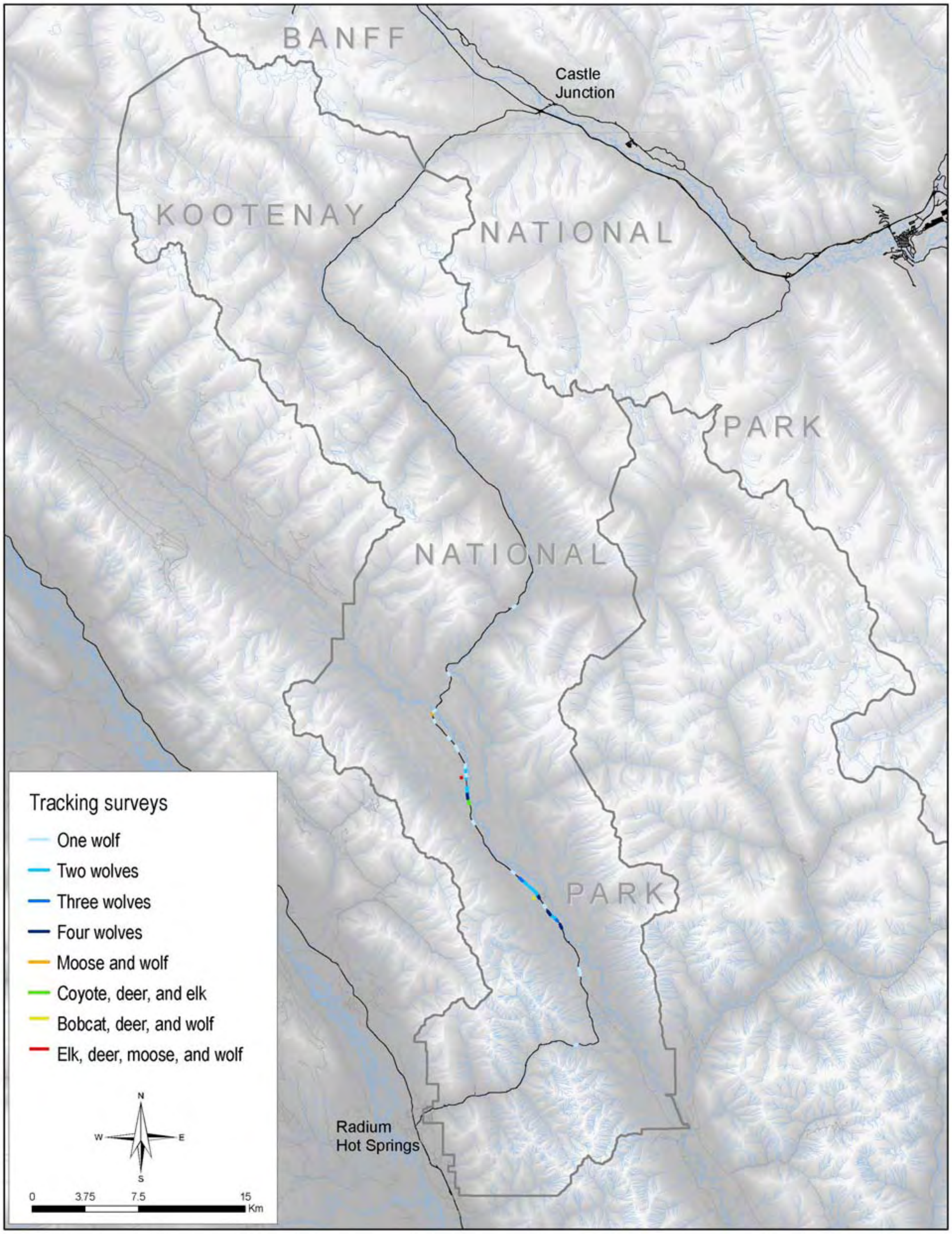

Figure 24. Wildlife observation data based on Osson (2002) and Spiteri (2007).

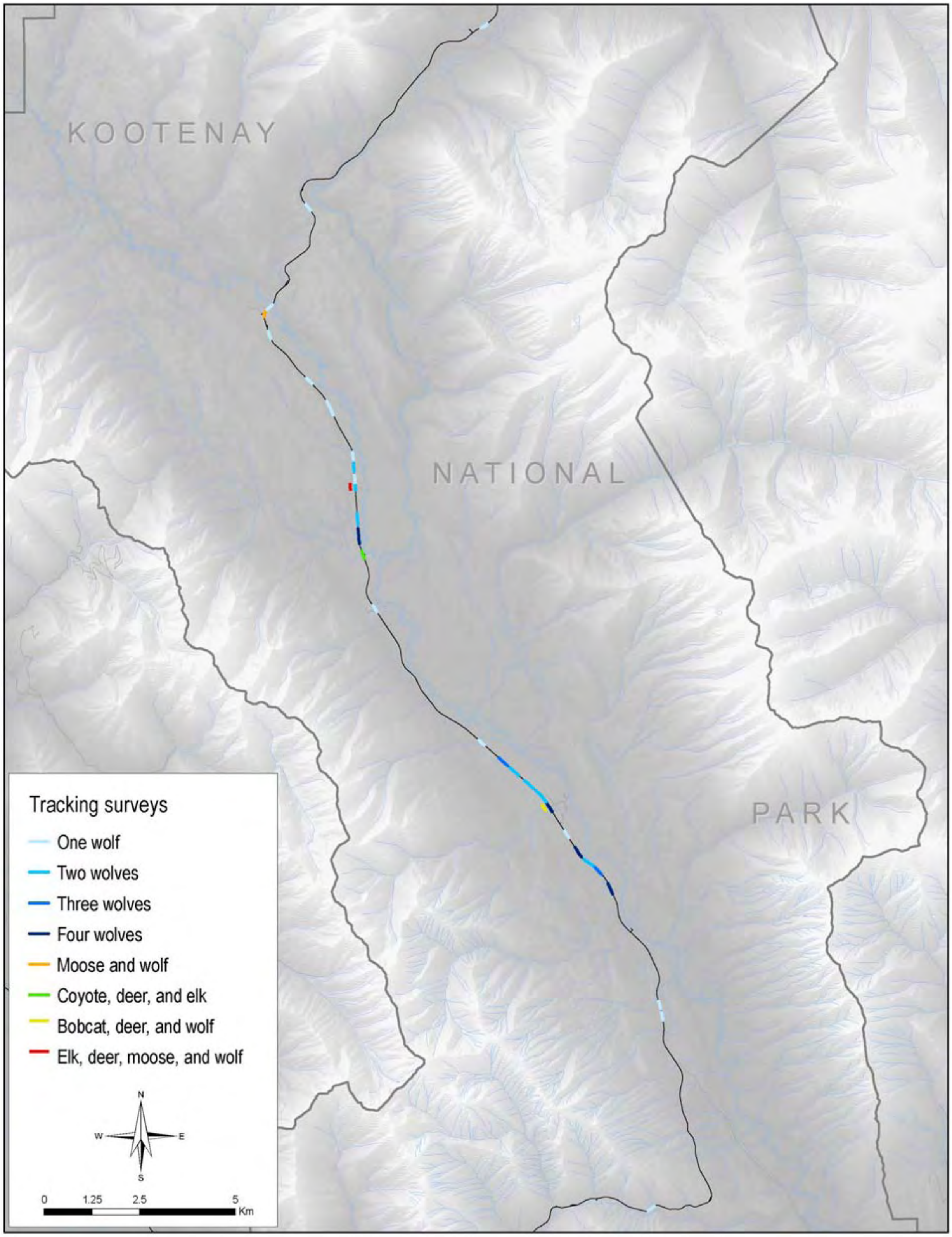

Figure 25. Wildlife observation data based on Osson (2002) and Spiteri (2007) (zoomed in on Kootenay Valley).

7. MITIGATION MEASURES

7.1 Recommended Mitigation Measures for Hwy 93S

Although there have been many mitigation measures suggested to reduce wildlife-vehicle collisions (WVCs), only a few of measures have the potential to substantially reduce WVCs (Huijser et al. 2007a, Huijser & Paul 2008). 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. Large boulders in the right-of-way as an alternative to wildlife fencing appear to have potential as a barrier to ungulates and may be an alternative to wildlife fencing. However, this measure should also still be considered experimental and would be mostly targeted at ungulates rather than other species groups. For a summary of the pros and cons of selected mitigation measures, including wildlife fencing, animal detection systems and large boulders in the right-of-way, see Table 18.

Closing and removing the road, or tunneling or elevating the road over long sections (e.g. hundreds of meters to tens of kilometers) are more effective in reducing WVCs that the measures described above. In addition, they allow for better habitat connectivity. However, road closure and road removal are considered unacceptable, and tunneling or elevating the road is extremely expensive and are typically only an option if the nature of the terrain, the physical environment, requires it. Therefore the authors of the report did not include road closure and removal or tunneling or elevating the road in the recommendations.

Using less sodium chloride or replacing sodium chloride with alternative deicing or anti-icing substances may substantially reduce the time certain species, e.g. bighorn sheep, spent on or alongside the road. However, such alternative substances may have other negative side effects and their implementation should also be considered experimental. The effectiveness of other mitigation measures in reducing WVCs is relatively low (<50%), impractical, not applicable, or unknown (Huijser et al. 2007a, Huijser & Paul 2008).

The authors of this report would like to emphasize that, although speed reduction and the enforcement of speed limits have important safety benefits, WVCs are unlikely to be substantially reduced as a result of increased speed management efforts on Hwy 93S through Kootenay and Banff National Park. The current speed limit is 90 km/h and even if one would be successful in keeping vehicles from speeding altogether (current operating speed, 85 percentile, is 111 km/h), a vehicle speed of 90 km/h is still estimated to be too fast to be able to result in a substantial reduction of WVCs (Huijser & Paul 2008). Nonetheless, should one decide to influence driver behavior when most wildlife-vehicle accidents occur, beneficial effects are most likely between 5 pm and mid night and between 5 am and 7 am (Figure 26). For a summary of the pros and cons of a reduction of the maximum speed limit, see Table 18.

Table 18. Pros and cons of selected mitigation measures.

Mitigation measure	Pros	Cons
Wildlife fencing	87% reduction in WVCs expected when combined with wildlife underpasses and overpasses.	Barrier for wildlife; combine with safe crossing opportunities. Affects landscape aesthetics. Potential animal intrusions at access roads/points, and fence ends. Potential mortality source for certain species under certain conditions (e.g. grouse, bighorn sheep). May provide drivers with a sense of security that may lead to higher speeds. Excluding r-o-w vegetation may lead to displacement or population reduction in species that depend on r-o-w vegetation (e.g. white-tailed deer, elk).
Large boulders	Substantial reduction in WVCs for most ungulates expected (e.g. deer, elk, and moose, but not for e.g. bighorn sheep and mountain goat). Not a barrier for species that can climb over the boulders. Less effect on landscape aesthetics than wildlife fencing	Not all species protected against WVCs. Barrier for most ungulates; combine with safe crossing opportunities. Potential animal intrusions at access roads/points, and end of boulder rows. Excluding r-o-w vegetation may lead to displacement or population reduction in species that depend on r-o-w vegetation (e.g. white-tailed deer, elk). Experimental measure.
Maximum speed limit reduction (including speed reduction during the night only, e.g. 70 km/h)	Local drivers (frequent visitors) may “learn” to respond to the maximum speed limit reduction (rather than respond to the design speed) with massive and consistent speed enforcement.	Current operating speed (111 km/h) is substantially higher than the maximum speed limit (90 km/h) already. Lowering speed limit may lead to increased speed dispersion and higher crash rates. Design speed will make drivers, especially to infrequent visitors, want to drive the perceived save speed, which is at least 90 km/h, probably even higher. Enforcing maximum speed limits substantially lower than the design speed will likely be experienced as “unjust”. Massive and consistent speed enforcement may need to be automated, which may conflict with policy or law. Experimental measure.

Animal detection systems	87% reduction in WVCs for large mammals expected, but this estimate in WVC reduction may change substantially as more data become available. Have the potential to provide wildlife with safe crossing opportunities anywhere along the mitigated roadway, in contrast to underpasses and overpasses which are typically limited in number and width. Are less restrictive to wildlife movement than fencing or crossing structures. They allow animals to continue to use existing paths to the road or to change them over time No road work or traffic control needed for installation (in contrast to wildlife underpasses and overpasses). Likely to be less expensive than wildlife crossing structures, especially once they are mass produced Can be installed over long road sections (multiple km) or at gaps in fence. This measure is somewhat mobile (except for foundations) and can be used at other locations should animals start crossing somewhere else.	Not suitable for very high traffic volumes. Detects large animals only. Animals are allowed to cross at grade; the design of the measure allows drivers to still be exposed to risk. The number of at grade crossings may not be sufficient to ensure long term population viability for all species. When combined with wildlife fencing, wildlife is directed to road at fence ends or at gaps, and this may cause Parks Canada to be liable in case of a collision, especially if the animal detection system may not have been working properly. Species that depend on r-o-w vegetation may use the at grade crossing to access that vegetation and end up in between the fences. This may be mitigated by boulder fields in r-o-w and electric mats on road, which may only function in summer. Some of the systems are not operational during the day. Curves, drops and rises in the right-of-way, access roads, pedestrians, winter conditions (including snow spray from snow plow and snow accumulation, can cause problems with the installation, maintenance and operation. The presence of poles and equipment in the right-of-way is a potential hazard to vehicles that run off the road. Animal detection systems can be aesthetically displeasing. Experimental measure.
Wildlife underpasses and overpasses	87% reduction in WVCs expected when combined with wildlife fencing. Well used by a wide variety of species. Can provide cover (e.g., vegetation, living trees, tree stumps) and natural substrate (e.g., sand, water) allowing better continuity of habitat than e.g. at grade crossing opportunities. Likely to have greater longevity and lower maintenance and monitoring costs than e.g. animal detection systems	The number, type, and dimensions of crossing opportunities may not be sufficient to ensure long term population viability for all species. This measure requires substantial road work and traffic control. This measure is not mobile.

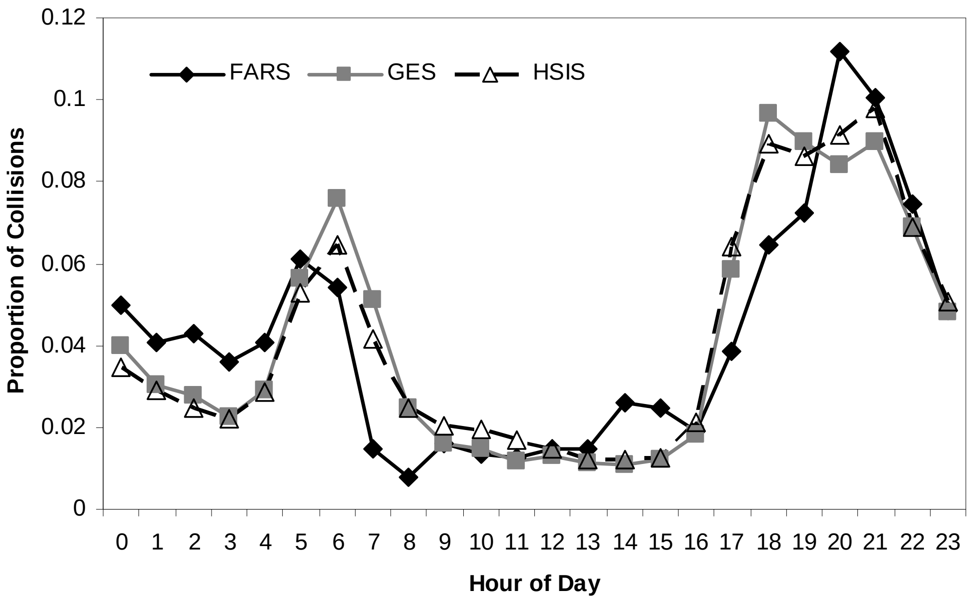

Figure 26. The hourly distribution of wildlife-vehicle collisions in the United States (Huijser et al. 2007a). Fatal Accident Reporting System (FARS) includes all crashes in the U.S. that involve a human fatality. Highway Safety Information System (HSIS) includes all reported crashes from Washington, California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio and Utah. General Estimates System (GES) are national accident estimates for the U.S., based on a small random sample of police accident reports from each sampling unit.

Wildlife fencing and the use of large boulders in the right-of-way increase the barrier effect of the road. These measures should typically only be used if safe crossing opportunities for wildlife are also provided for. Such crossing opportunities can consist of at grade crossings at a gap in the barrier, with or without additional warning signals for drivers (e.g. animal detection systems), or wildlife underpasses and overpasses.

The authors of this report consider animal detection systems and wildlife fencing (Figure 27 and 28), in combination with wildlife underpasses and overpasses, to be the primary recommended mitigation measures for the reduction of WVCs along Hwy 93 South through Kootenay National Park and adjacent road sections. However, animal detection systems should still be considered experimental whereas the performance estimates for wildlife fencing and underpasses and overpasses are much more robust. Also, care must be taken to reduce false detections, for example if pedestrians are present in the right-of-way, and animal detection systems are less effective if a high percentage of the traffic is not local or if drivers are unlikely to respond to warning signals (perhaps drivers of large vehicles are less likely to reduce speed than drivers of small vehicles). The authors of this report also consider public information and education, experiments with alternatives to road salt, and experiments with large boulders in the right-of-way (Figure 29) mitigation measures to have potential for reducing WVCs along Hwy 93 South through Kootenay National Park and adjacent road sections. However, these mitigation measures are classified as either "supportive" (secondary measures) or experimental, and Parks Canada has indicated that experimental techniques should be avoided or minimized in the mitigation plan (Personal Communication, Alan Dibb, Parks Canada).

Figure 27. A 2.4 m high fence with buried apron along the Trans-Canada Highway in Banff National Park (Phase 3-A) (© Tony Clevenger).

Figure 28. A 2.4 m high wildlife fence along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (© Marcel Huijser, WTI-MSU).

Figure 29. Large boulders placed in the right-of-way as a barrier to elk and deer along State Route 260 in Arizona, USA (© Marcel Huijser).

While wildlife fencing is typically placed at the edge of the right-of-way or at least outside the clear zone, wildlife fencing typically angles towards the road at wildlife overpasses or underpasses to minimize the length (= road width) of these crossing structures. If needed, e.g. at at grade crossing opportunities (e.g. gap in fence with an animal detection system, fence ends) a fence that comes close to the road may have to be combined with a guard rail or concrete barrier for safety reasons (Figure 30). Alternatively, rocks may be installed to form a boulder field to stimulate ungulates in crossing the road rather than wandering off in the right-of-way and getting trapped in between the wildlife fencing (Figure 31). Wildlife guards have also been used on major roads at fence ends (Figure 32).

Figure 30. Fence end brought close to the road with a concrete barrier for safety along Hwy 93S in Banff National Park, just west of Castle Jct (© Marcel Huijser, WTI-MSU).

Figure 31. The Boulder Field at the Fence End at Dead Man's Flats Along the Trans Canada Highway East of Canmore, Alberta, Canada (© Bruce Leeson).

Figure 32. Wildlife guard at a fence end on the 2-lane US Hwy 1 on Big Pine Key, Florida, USA (© Marcel Huijser).

Animals may end up in between fences or other barriers placed along the transportation corridor posing a safety risk and exposing the species concerned to road mortality. Therefore, absolute barriers, such as wildlife fencing, should typically be accompanied with escape opportunities for animals that have ended up in between the fences (Reed et al. 1974, Ludwig & Bremicker 1983, Feldhamer et al. 1986, Bissonette & Hammer 2000). Jump-outs or "escape ramps" are sloping mounds of soil placed against a backing material on the right-of-way side of the fence (Figure 33 through 35). The highway fence is tied in to the edges of the jump-out. Jump-outs are designed to allow animals caught in between the fences to jump out of the right-of-way. At the same time, jump-outs should not allow animals to jump into the right-of-way area. Little is known about the appropriate height for jump-outs. The appropriate height of jump-outs is likely dependent on the main species of interest and the terrain (e.g. up-slope or down-slope), but they are typically 1.6-2.4 m (5-8 ft) in height.

Figure 33. A jump-out along a 2.4 m (8 ft) high fence along US 93 in Montana, USA (© Marcel Huijser).

Figure 34. A jump-out along a 2.4 m (8 ft) high fence along US 93 in Montana, USA (© Marcel Huijser).

Figure 35. A jump-out along a 2.4 m (8 ft) high fence with smooth metal to prevent bears from climbing the jump-out the wrong way. Along the Trans Canada Highway, Lake Louise area, Banff National Park, Canada (© Marcel Huijser, WTI-MSU).

Fences intersect with access roads, and access points for e.g. hikers. Depending on the traffic volume and purpose of the road, wildlife guards (Figure 36, 37) or gates (Figure 38, 39) can be installed at access roads. In addition, access points for people, e.g. hikers, can be provided for (Figure 40 and 41).

Figure 36. A wildlife guard at an access road of the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (© Marcel Huijser)

Figure 37. A wildlife guard at an access road of the 2-lane US Highway 1 on Big Pine Key, Florida, USA (© Marcel Huijser)

Figure 38. A gate at an access road of the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (© Marcel Huijser)

Figure 39. A gate at an access road of the 2-lane US Highway 1 on Big Pine Key, Florida, USA (© Marcel Huijser)

Figure 40: Swing gate in fence (spring loaded) allowing access for people, also when there is snow on the ground, along the Trans-Canada Highway in Banff National Park, Alberta, Canada (© Adam Ford, TCH research project / WTI-MSU).

Figure 41: Access point for people along US93, south of Missoula, Montana, USA (© Marcel Huijser). This type of gate may be a barrier for ungulates.

7.2 Distance between Safe Crossing Opportunities

When wildlife fencing is installed alongside a road, the barrier effect of the road corridor is increased. Depending on the species concerned, a wildlife fence may be an absolute or a nearly complete barrier. Such barriers in the landscape are to be avoided as they isolate animal populations, and smaller and more isolated populations have reduced population survival probability. Therefore, when a wildlife fence is installed, safe crossing opportunities for wildlife should be provided for as well. This section discusses the distance between safe crossing opportunities.

The spacing of safe crossing opportunities for wildlife can be calculated in more than one way and is dependent on the goals one may have. Examples of possible goals are:

- Provide permeability under or over the road for ecosystem processes, including but not restricted to animal movements. Ecosystem processes include not only biological processes, but also physical processes (e.g. water flow).
- Allowing a wide variety of species to change their spatial distribution drastically, for example in response to climate change.
- Maintaining or improving the population viability of selected species based on their current spatial distribution. This includes striving for larger populations with a certain degree of connectivity between populations (allowing for successful dispersal movements).
- Providing the opportunity for individuals (and populations) to continue seasonal migration movements (e.g. big horn sheep, white-tailed deer).
- Allowing individuals, regardless of the species, that have their home ranges on both sides of the highway to continue to use these areas. This may result in a road corridor that is permeable for wildlife, at least to a certain degree, and at least for the individuals that live close to the road.

A further complication is that individuals that disperse, that display seasonal migration, or that live in the immediate vicinity of a road may display differences in behavior with regard to where and how they move through the landscape, how they respond to roads, traffic, and associated barriers (e.g. wildlife fencing), and their willingness to use safe crossing opportunities. For example, dispersing individuals may be far away from the areas where one is used to seeing them, they may not move through habitat that we may expect them to be in, they typically travel long distances, much further and quicker compared to resident individuals, but successful dispersers may also stay away from roads and traffic, and other types of human disturbance. Safe crossing opportunities may not be encountered by dispersing individuals as they are new in the area and are not familiar with their location, and when confronted with a road or associated wildlife fence they may return or change the direction of their movement before they encounter and use a safe crossing opportunity. Furthermore, if dispersing individuals do encounter a safe crossing opportunity, they may be more hesitant to use them compared to resident individuals that not only know about their location, but that also have had time to learn that it is safe to use them. Since dispersal can be a relatively rare phenomenon, one may not be able to afford a dispersing individual to fail. Therefore, despite the fact that dispersers travel much further than resident individuals, designing safe crossing opportunities for dispersers does not automatically mean that one can allow for a greater distance between safe crossing opportunities.

While population viability analyses can be very helpful to compare the effectiveness of different configurations of safe crossing opportunities, the data required for such population viability analyses are often unavailable or incomplete. Furthermore, the collection of such data is typically very time consuming and expensive, especially if multiple species are to be investigated. For this report the authors choose a simpler approach. For all species observed in the mitigation zones (see Figure 20, Table 15), home range sizes, and the diameter of these home ranges were estimated (Table 19 through 21). Home range sizes for species that may not be hindered by the fence because they can either fly over it (e.g. birds) or crawl through it (e.g. amphibian, reptiles, small mammals) were not calculated.

Table 19. Home range size and diameter estimates for the large ungulates included when calculating mortality clusters and mitigation zones (see section 3.2). The estimates relate to female individuals where possible, and local or regional data weighed relatively heavily in the final estimation of the home range size.

Species	Home range (ha) and diameter (m)	Source(s)
White-tailed deer	70 ha 944 m	70.5 ha for adult females in summer (Leach & Edge, 1994), <80 in summer (Mundinger, 1981), 60-70 ha for females in summer (review in Mackie et al. 1998), 89 ha (range 17-221 ha) for females in summer and 115 ha (range 19-309 ha) in winter (review in Mysterud et al., 2001)
Mule deer	300 ha 1,955 m	301 ha on average for males and females in winter (D'Eon & Serrouya, 2005), 90-320 ha for adult females in summer and 80-500 ha in winter (review in Mackie et al. 1998), 617 ha (range 25-4,400 ha) for females in summer and 1,267 ha (range 32-9,070 ha) in winter (review in Mysterud et al., 2001)
Elk	5,000 ha 7,981 m	3,769 ha (range 820-9,520 ha) for females in summer and 181 ha (range 152-210 ha) in winter (review in Mysterud et al., 2001), 5,296 ha for adult females in summer and 10,104 ha in winter (Anderson et al., 2005), 8,360-15,720 ha for elk populations (Van Dyke et al., 1998)
Moose	2,500 ha 5,643 m	2,612 ha (range 210-10,300 ha) for females in summer and 2,089 ha (range 200-11,300 ha) in winter (review in Mysterud et al., 2001)
Mountain goat	300 ha, 1,955 m	280 ha for adult males, 480 ha for adult females (Singer & Doherty, 1985)
Bighorn sheep	900 ha 3,386 m	541 ha for females (review in Demarchi et al., 2000), 920 ha (range 650-1,140 ha) for females in summer and 893 (range 880-1,320 ha) in winter (review in Mysterud et al., 2001), 640-3,290 ha (review in Demarchi et al., 2000)

Table 20. Home range size and diameter estimates for the large and medium sized carnivores included when calculating mortality clusters and mitigation zones (see section 3.2). The estimates relate to female individuals where possible, and local or regional data weighed heavily in the final estimation of the home range size.

Species	Home range (ha) and diameter (m)	Source(s)
Wolverine	20,000 ha 15,962 m	16,700 ha (range 7,600-26,900 ha) for females (Banci & Harestad, 1990), 10,500 for adult females (Whitman et al., 1986), 38,800 for females (review in Lindstedt et al., 1986), 32,500-40,500 ha for females (Krebs et al., 2007)
Bobcat	2,500 ha 5,643 m	1,780 ha for adult female (Knowles, 1985), 1,930 ha for females (review in Lindstedt et al., 1986), 3,120 ha for females (Litvaitis et al., 1986)
Canada lynx	15,000 ha 13,823 m	2,800 ha (range 1,110-4,950 ha) for adults (Brand et al., 1976), 9,000 ha (range 5,800-12,100 ha for adult females (Squires & Laurion, 2000), 20,600 ha (range 7,700-40,800 ha) for females (Apps, 2000)
Cougar	4,000 ha 7,138 m	3,500 ha (range 1,900-5,100 ha) for adult females in summer and 2,600 ha (range 1,400-4,300 ha) in winter (Spreadbury et al., 1996), 6,730 ha for females (review in Lindstedt et al., 1986), 9,700 ha (range 3,900-22,700 ha) for adult females in summer and 8,700 (range 3,100-23,900 ha) in winter (Ross & Jalkotzy, 1992)
Coyote	2,500 ha 5,643 m	1,130 ha (range 280-3,200 ha) (Gese et al., 1988), 2,010 ha (range 1,600-2,420 ha) for females (review in Lindstedt et al., 1986), 2,420 ha (range 880-5,460 ha) for adult females (Andelt & Gipson, 1979), 3,186 ha (range 670-9,140 ha) for females (review in Laundré & Keller, 1984)
Wolf	50,000 ha 25,238 m	6,250 ha (range 700-6,800 ha) (review in Lindstedt et al., 1986) 26,000-67,500 ha for a large pack (Whitaker, 1997)
Black bear	4,000 ha 7,138 m	1,960 ha for females (Young & Ruff 1982), 5,960 ha (range 2,300-16,000 ha) for adult females (McCoy, 2005)
Grizzly bear	25,000 ha 17,846 m	22,700 ha (range 3,500-88,400 ha) for adult females (Gibeau et al., 2001), 28,500 ha (112-482 ha) for adult females (Servheen, 1983)

Table 21. Home range size and diameter estimates for other species seen inside the mitigation zones. The estimates relate to female individuals where possible, and local or regional data weighed heavily in the final estimation of the home range size.

Species	Home range (ha) and diameter of home range (m)	Source(s)
Pine marten	500 ha 2,524 m	200 ha (range 0.7-2.3 ha) for females (Poole et al., 2004), 1,300-3,900 ha (Whitaker, 1997)
Porcupine	50 ha 798 m	15.4 (range 1.5-58.8 ha) for females (Morin et al., 2005), 70.1 ha for females (Smith, 1979)
Snowshoe hare	5 ha 252 m	5.8 ha (O'Farrell, 1965), 5.1 ha for females (de Bellefeuille et al., 2001)
Striped skunk	300 ha 1,955 m	300 ha (Frey & Conover, 2006) 108 ha (range 19-266 ha) (Bixler & Gittleman, 2000)
Beaver	n/a	Linear, along streams
Hoary marmot	5 ha 252 m	0.8 ha (interpreted from Karels et al., 2004), 28.3 ha for social groups (interpreted from Kyle et al., 2007)
Badger	4,000 ha 7,138 m	240-1,700 ha (Whitaker, 1997), 3,400 ha (Goodrich & Buskirk, 1998), 4,150 ha (range 1,800-7,900 ha) for females (Kinley & Newhouse, 2008)
Red fox	1,500 ha 4,371 m	1,611 ha (range 277-3,420 ha) (Jones & Theberge, 1982), 350 ha (Frey & Conover, 2006)

The distance between safe crossing opportunities was set to be equal to the diameter of the home range of the species concerned (Figure 42). This allowed individuals that have the center of their home range on the road to have access to at least one safe crossing opportunity. However, individuals that may have had their home range on both sides of the road do not necessarily have access to a safe crossing opportunity (Figure 43). Finally, this approach assumed homogenous habitat and distribution of the individuals and circular home ranges, while in reality habitat and habitat quality may vary greatly, causing variations in density of individuals and irregular shapes home ranges.

The authors of this report would like to emphasize that this approach does not necessarily result in viable populations for every species of interest, and that not every individual that approaches the road and associated wildlife fence, will encounter and use a safe crossing opportunity. In addition, the approach described above is not necessarily the only approach or the approach that addresses the barrier effect of the road corridor and associated fencing sufficiently for all species concerned. However, the authors do think that the approach chosen is consistent, practical, based on the available data (or lack thereof), and likely to result in considerable permeability of the road corridor and associated wildlife fencing for a wide array of species.

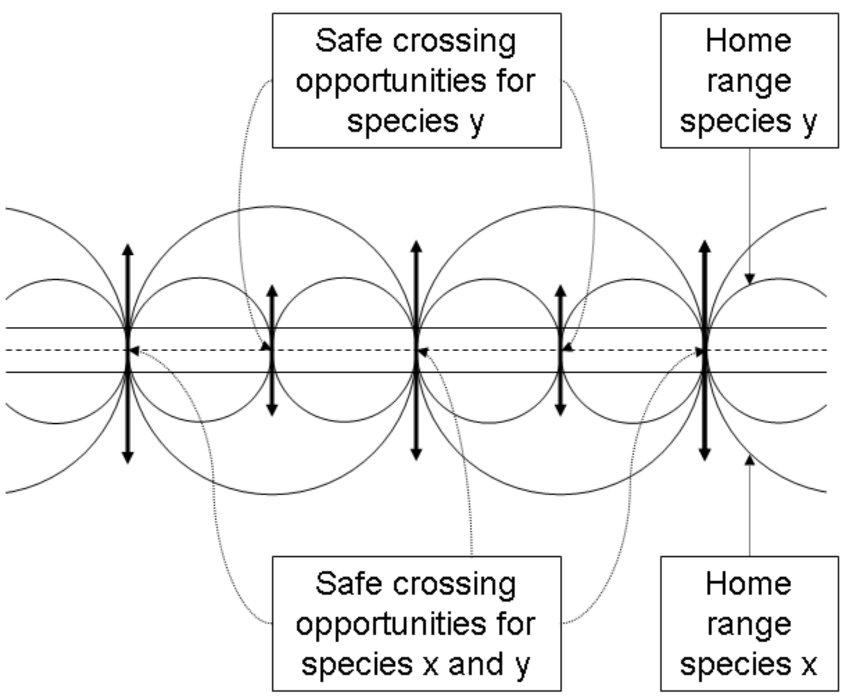

Figure 42. Schematic representation of home ranges for two theoretical species projected on a road and the distance between safe crossing opportunities (distance is equal to the diameter of their home range).

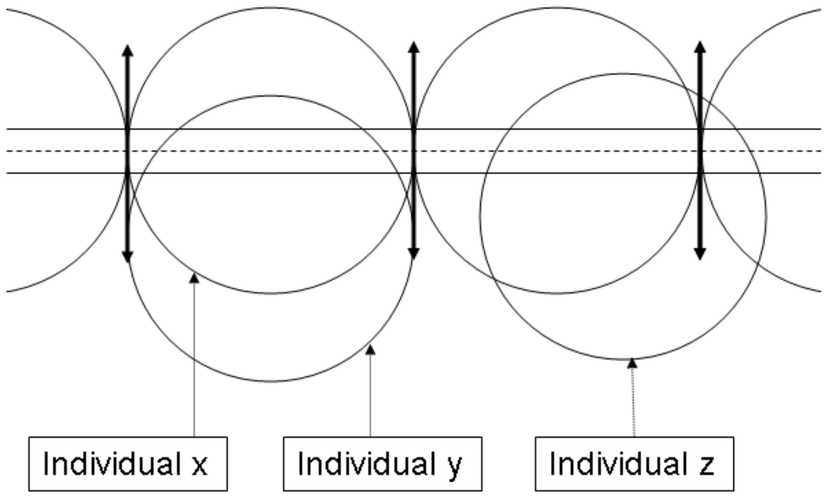

Figure 43. Schematic representation of home range for an individual (x) that has the center of its home range on the center of the road (access to two safe crossing opportunities), an individual (y) that has the center of its home range slightly off the center of the road exactly in between two safe crossing opportunities (no access to safe crossing opportunities), and an individual (z) that has the center of its home range slightly off the center of the road but not exactly in between two safe crossing opportunities (access to one safe crossing opportunity).

7.3 Safe Crossing Opportunity Types

The authors of this report distinguished six different types of safe crossing opportunities for potential implementation on and along the roads in the study area (Table 22) (Figure 44 through 52). Note that there are other types of crossing structures, e.g. for arboreal species, amphibians, but these are not included in this report because most of these species are able to crawl through the wildlife fence. In addition, the six types of crossing structures listed are likely to be used by e.g. amphibians, reptiles, (semi-)arboreal species, and small mammals, given certain environmental conditions or modifications. For example, if wet habitat is present or created on or nearby an overpass or underpass, amphibians and other semi-aquatic species are more likely to use the crossing opportunity. Similarly, aquatic species are likely to use a crossing opportunity if the underpass is combined with a stream or river crossing. Stream characteristics and stream dynamics must be carefully studied to ensure that the conditions inside the crossing structure are and remain similar to that of the stream up- and downstream of the structure. Such parameters include e.g. water velocity, variability in water velocity, erosion of substrate inside the crossing structure, or up- and downstream of the structure, and the implications of high and low water events, including debris and potential maintenance issues. If terrestrial animals are to use the underpass as well, a minimum path width of 0.5 m is recommended for small and medium mammals, and 2-3 m for large mammals (Clevenger, unpublished data). Furthermore, small mammals increase their use of wildlife underpasses and overpasses if cover (e.g. tree stumps, branches and rocks) is provided for continuous travel through or over the crossing structure. Nonetheless, one may choose to provide additional safe crossing opportunities specifically designed for e.g. amphibians, reptiles, semi-arboreal species, and small mammals (soil and air humidity, cover, woody vegetation that spans across or under the road or canopy connectors such as ropes or other material) (e.g. Kruidering et al. 1995).

While Table 22 classifies underpasses based on their dimensions, there is no generally agreed upon definition of different types of underpasses. One may also choose to modify the dimensions of an underpass based on the species of interest and the physical environment at the location of the underpass.

Table 23 provides an overview of the suitability of the six different types of safe crossing opportunities for the species of interest. When evaluating the suitability, the authors assumed no human co-use of the crossing opportunities. The suitability of the different types of safe crossing opportunities is not only influenced by the size of the species and their habitat, but also by behavior. Most animal detection systems only detect large mammals and are therefore by definition not suitable for medium and small species. Because the suitability of the different safe crossing opportunities depends on the species, and large landscape connectors (e.g. tunneling or elevated road sections) are rare, providing a variety of different types of safe crossing opportunities generally provides habitat connectivity for more species than implementing only one type of crossing structure, even if that structure is relatively large.

Table 22. Dimensions of the mitigation measures recommended for implementation on or along the roads in the study area.

Safe Crossing Opportunity	**Dimensions (as seen by the animals)**		**Safe Crossing Opportunity**	**Dimensions (as seen by the animals)**
Wildlife overpass	50 m wide		Medium mammal underpasses	0.8-3 m wide, 0.5-2.5 m high
Open span bridge	12 m wide, ≥5 m high		Small-medium mammal pipes	0.3-0.6 m in diameter
Large mammal underpass	7-8 m wide, 4-5 m high		Animal Detection system	n/a

Figure 44. Red Earth overpass on the Trans-Canada Highway (© Tony Clevenger, WTI).

Figure 45. Wildlife overpass ("Schwarzgraben") across a 2-lane road (B31) in southern Germany (© Edgar van der Grift).

Figure 46. An open span bridge along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (across Spring Creek, south of Ravalli) (© Marcel Huijser).

Figure 47. A large mammal underpass (7-8 m wide, 4-5 m high) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (south of Ravalli) (© Marcel Huijser).

Figure 48. A medium mammal box culvert (1.2 m wide, 1.8 m high) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (south of Ravalli) (© Marcel Huijser).

Figure 49. A medium mammal culvert (2 m wide, 1.5 m high) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (south of Ravalli) (© Marcel Huijser).

Figure 50. A small-medium mammal pipe ("badger pipe") in The Netherlands (© Marcel Huijser).

Figure 51. An animal detection system (infrared break-the-beam system manufactured by Calonder Energy, Switzerland) at a gap in a wildlife fence near 't Harde, The Netherlands (© Marcel Huijser).

Figure 52. An animal detection system (microwave radio signal break-the-beam system manufactured by Sensor Technologies & Systems, Scottsdale, AZ) installed along a 1 mile (1,609 m) section of US Hwy 191 between Big Sky and West Yellowstone in Yellowstone National Park (© Marcel Huijser, WTI-MSU).

Table 23. Suitability of different types of mitigation measures for various species. ● Recommended/Optimum solution; ⭘ Possible if adapted to local conditions; ⊗ Not recommended; ? Unknown, more data are required; — Not applicable (mostly based on Clevenger, unpublished data).

	Wildlife overpass	Open span bridge	Large mammal underpass	Medium mammal underpass	Small-medium mammal underpass	Animal detection system
Ungulates						
Deer sp.	●	●	●	⊗	⊗	●
Elk	●	●	⭘	⊗	⊗	●
Moose	●	●	⭘	⊗	⊗	●
Mountain goat	●	●	⭘	⊗	⊗	●
Bighorn sheep	●	●	⭘	⊗	⊗	●
Carnivores						
Wolverine	●	?	?	?	⊗	⊗
Bobcat	●	●	●	●	●	⊗
Canada lynx	●	?	?	?	⊗	⊗
Cougar	●	●	●	⊗	⊗	⊗
Coyote	●	●	●	●	●	⊗
Wolf	●	●	⭘	⊗	⊗	⊗
Black bear	●	●	●	⊗	⊗	●
Grizzly bear	●	⭘	⭘	⊗	⊗	●
Additional						
Pine marten	●	⭘	⭘	●	●	⊗
Porcupine	●	●	●	?	?	⊗
Snowshoe hare	●	●	●	?	?	⊗
Striped skunk	●	●	●	●	●	⊗
Beaver	⊗	⭘	⭘	⭘	⊗	⊗
Hoary marmot	●	●	●	●	●	⊗
Badger	●	●	●	?	?	⊗
Red fox	●	●	●	●	●	⊗

7.4 Site Specific Recommendations for Mitigation Measures

This section provides recommendations for the location and type of safe crossing opportunities. Ideally, the area would have been investigated for the exact location of mitigation measures and existing features such as creek or river bridges. However, the time constraints (begin and end date) in combination with abundant snow did not allow the research personnel to see what the conditions were at the field locations. Therefore, the researchers encourage the users of this report to be flexible when interpreting the recommendations. Furthermore, the researchers have provided tools to help users of this report compile alternate mitigation configurations (section 8.7).

7.4.1 Kootenay and Banff National Park

The road section through Sinclair canyon and the entire Kootenay Valley has many highway mortality clusters, and because of the buffer zones and minimum gap sizes applied (see section 3.3), the authors of this report propose a 46.3 km long road section with wildlife fencing and safe crossing opportunities for wildlife. Large boulders in the right-of-way, as an alternative to wildlife fencing may be considered in areas where deer and elk are the main concern, but not in areas where e.g. bighorn sheep are a concern. Alternatives to road salt appear not as important in Kootenay and Banff National Park as they are on Mile Hill, just south of Radium Hot Springs (see section 7.4.2). Bighorn sheep are especially attracted to sodium chloride, but the seasonal distribution of bighorn sheep-vehicle collisions inside Kootenay and Banff National Park (Figure 53) shows that bighorn sheep are mostly hit in summer and fall, probably because the two Parks are mostly summer range rather than winter range (Personal Communication Alan Dibb, Parks Canada). Therefore the authors of this report are less concerned about a wildlife fence and potentially denying bighorn sheep access to sodium chloride on the road sections through Kootenay and Banff National Park compared to Mile Hill near Radium Hot Springs.

The wildlife fence is proposed to start just north of the Radium Hot Springs Pools (Figure 55). Perhaps the fence can be tied in to the slopes at this location. The road section with the hot spring pools and the parking areas across from the pools have heavy pedestrian traffic and combined with landscape aesthetics concerns, the authors of the report propose to leave this area unmitigated and accept ongoing bighorn sheep highway mortalities in this road section. However, this is an area where a further reduction of the vehicle speed limit (currently 50 km/h) may be possible because of the heavy pedestrian traffic. Such a measure may have to be combined with traffic calming measures though, e.g. speed bumps as the speed limit should generally reflect the road design. One may also decide to start the fence slightly further to the north (at about the 2.3 km point) and not fence in the parking area at about the 2.2 km point.

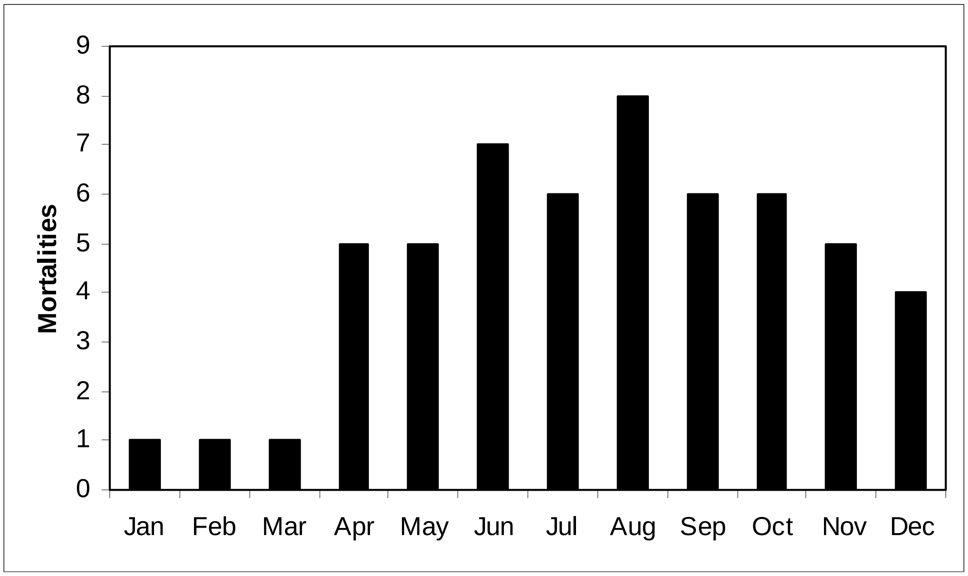

Figure 53. Seasonal distribution of road mortality observations of bighorn sheep in Kootenay and Banff road sections (1975- 2007), observed within 100 m Hwy 93S.

At the north end the fence is proposed to end at 48.3 km. However, because of the difficulty of providing either an overpass or underpass for the mountain goats at the cliff at the 47.2 km point, the authors of this report suggest, as an alternative, ending the fence at about 47.2, tying the wildlife fence into the cliff (west side), and ending the wildlife fence where the river comes close to the road on the east side (about 47.2 point). Mountain goats, while seen frequently licking minerals from the cliff on the west side of the road are rarely hit by traffic. Also, this would eliminate the negative effects of a wildlife fence in between the road and the river where there is no cover and where it would be highly visible to travelers. Nonetheless, one may choose to install an animal detection system at the fence ends (about 47.2 km point) to protect the mountain goats and the road section below the cliff with minimal impacts on landscape aesthetics compared to a fence.

The authors of this report would like to call attention to the possibility that fencing the entire Kootenay Valley may cause the white-tailed deer population to crash or be displaced. Similarly, the elk population may not grow again to previous levels, because they now also can no longer access the right-of-way vegetation. These negative side effects of the fence relate to unnatural and linear vegetation in an otherwise more or less natural environment though. Furthermore, species such as white-tailed deer and elk may benefit from extensive natural burns in the Vermilion Valley (2001 and 2003 (Personal Communication, Alan Dibb, Parks Canada)) and scheduled prescribed burning in the Kootenay Valley (Figure 54). Such large scale and relatively rare events may cause major changes in the ecosystem, not only with regard to the absolute and relative abundance of individual species, but also with regard to their spatial distribution. For example, white-tailed deer, and possibly also elk and grizzly bear, may become more numerous in the Vermilion Valley in the next years. This may also change where wildlife-vehicle collisions occur and where mitigation measures are most needed, at least on short term.

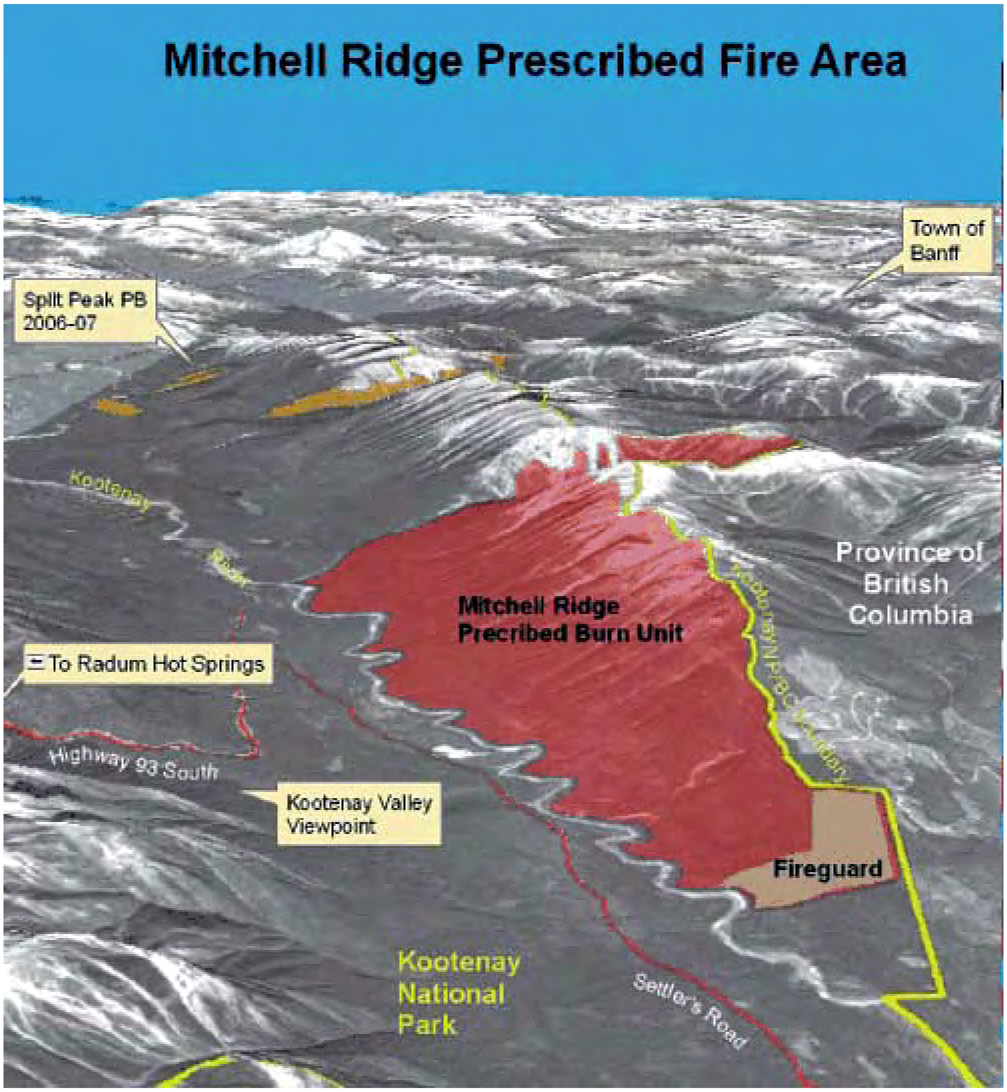

Figure 54. Area for proposed prescribed burning (shown in red) in the Kootenay Valley.The red area delineates the total boundary of the prescribed burning area, but the actual fire could be 1/3 to 2/3 the total size of the unit, and may be burned in multiple stages over several years (© Parks Canada).

Access roads in the sections of fencing (e.g. Park facilities, Settler's road, campgrounds, picnic areas) may be provided with a wildlife guard (modified cattle guard) or gates. In addition, wildlife jump-outs should be provided for at regular intervals, perhaps as frequently as one every 300 m (this would apply to both sides of the road) (Bissonette & Hammer 2000).

Animal detection systems may be installed as an alternative to wildlife fencing. However, curvy road sections such as in Sinclair Canyon and along Sinclair Creek would require relatively many sensors and are not recommended. In the Kootenay Valley there are many straight road sections and an animal detection system could be considered, especially if one is concerned about how a wildlife fence would deny access to the grass-herb vegetation in the right-of-way for white-tailed deer, and, should their population increase again to previous levels, elk. Note that drivers would not habituate to these signs as they are only activated when wildlife has been detected. However, since animal detection systems should still be considered experimental, the authors of this report do not recommend applying them over tens of kilometers before gaining some more experience with them at shorter road sections.

In road sections with wildlife fencing, safe crossing opportunities should be provided for. A safe crossing opportunity can consist of a wildlife overpass, a wildlife underpass, or an "at grade crossing" at a gap in the wildlife fence, combined with an animal detection system. If "at grade crossings" are considered, care should be taken to prevent animals from wandering off into the right-of-way and getting caught in between the fences. This may be a particular problem with white-tailed deer in the Kootenay Valley, as the authors of this report suspect that they are especially attracted to the vegetation in the right-of-way that the wildlife fence would have denied them access to. Furthermore, bighorn sheep may still be somewhat attracted to road salt, even in seasons other than winter, and a gap in a fence would allow access to this resource and may result in them spending substantial time on the road. Therefore, at grade crossing opportunities should perhaps only be considered in areas where deer, elk and bighorn sheep are scarce.

The authors of this report propose to provide safe crossing opportunities in the form of wildlife overpasses and wildlife underpasses (Figure 55, Appendix J). However, one may also consider gaps in fences in combination with animal detection systems to provide for at grade crossing opportunities (see Table 18 for pros and cons). Should at grade crossing opportunities be implemented, extreme care must be taken to discourage wildlife, especially white-tailed deer and elk, from wandering off in between the fences to forage on the grass-herb vegetation in the right-of-way. Bringing the fence close to the road at these locations, with or without the use of boulder fields may help, and an electric mat (ElectroMAT™, ElectroBraid™) that is embedded in the road surface, or laid on top of the road, may also be considered to discourage animals from walking off to the sides on the roadway (ElectroBraid 2008a). Reports on the manufacturer's website suggest that the electric matt holds up when exposed to snowplows and that it can function throughout the winter (ElectroBraid 2008b). Nonetheless, such at grade crossing opportunities should be seen as experimental and their effectiveness should be carefully evaluated before implementing them on large scale.

The location of crossing structures in the road sections with wildlife fencing (the mitigation zones) is primarily based on the wildlife observation clusters (all recorded observations of all wildlife species, dead or alive, on or within 100 m from the road). However, not all locations may be suitable for a crossing structure. Wildlife overpasses may be most feasible where the areas on both sides of the road are some what elevated already and wildlife underpasses are most feasible in fill slopes or areas that are relatively flat on both sides of the road. Therefore, not all crossing structure locations coincide with a wildlife observation cluster.

The authors of this report strived to have at least one crossing opportunity for each wildlife observation cluster. However, if crossing structures were substantially closer than the diameter of the home range of the "primary target species" (see next paragraph), only one of the structures was proposed. On the other hand, some wildlife observation clusters are over a road length that is greater than the home range of the primary target species, and here multiple crossing structures were provided within a wildlife observation cluster.

The authors of this report defined a "primary target species" as follows: species for which at least five observations occurred within a wildlife observation cluster or species that represented at least 5% of all observations within a wildlife observation cluster. If grizzly bear sightings were reported from within 1 km of the crossing structure or within in the cluster concerned, grizzly bears were listed as a primary target species between brackets, regardless of the number or percentage of grizzly bear observations. Appendix J lists the primary target species for each suggested safe crossing opportunity.

The authors of this report do not think that small and medium sized mammals were reliably reported, either dead or alive, and using the minimal data (e.g. 3 hoary marmot observations and 14 snowshoe hare observations in 33 years in the mitigation zones) appear insufficient to propose locations for medium mammal underpasses and small-medium mammal pipes. However, in areas where specific species are believed to be present (e.g. based on local knowledge, including from Parks Canada personnel), the diameter of the home range of the species concerned may serve as an indication of the spacing between such crossing opportunities. One should avoid having long

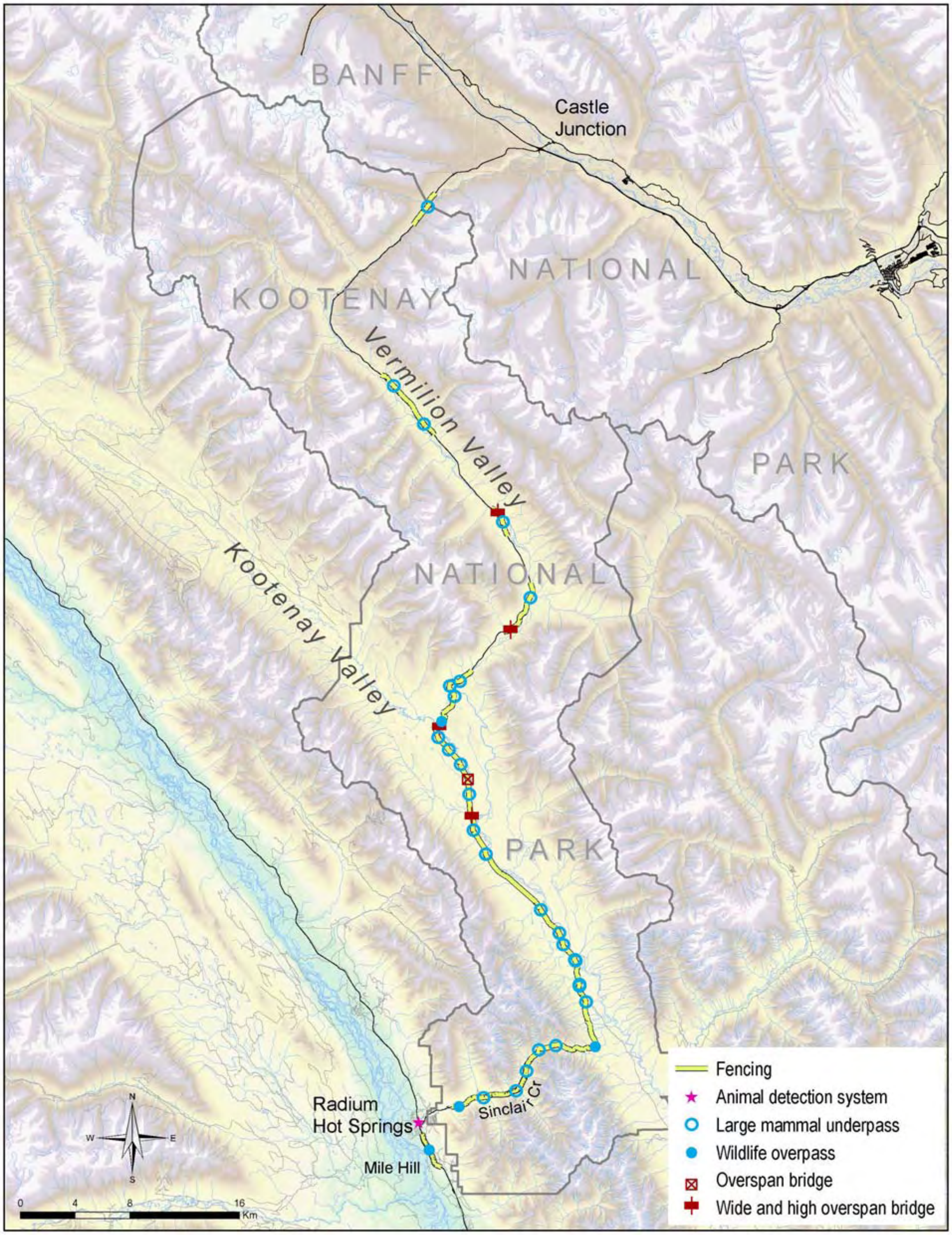

Figure 55. Suggested Mitigation Measures for the road sections in Kootenay and Banff National Park and in and around Radium Hot Springs.

road sections with no crossing opportunities at the appropriate intervals for small and medium mammals at road sections from where no observations were reported as this may reflect reporting effort rather than the true absence of certain species. Therefore, one may simply choose to install small-medium mammal pipes e.g. every 250 m and a medium mammal underpass every 2 km, in addition to large mammal underpasses.

7.4.2 Road Sections in and Around Radium Hot Springs

There are two road sections that have a concentration of bighorn sheep-vehicle collisions on the road sections in an around Radium Hot Springs; Mile Hill and just north of the intersection in Radium Hot Springs (see also Table 6, Figure 17).

7.4.2.1 Mile Hill

Bighorn sheep are crossing the road on Mile Hill because their winter range is on both sides of the highway (Figure 56). Interestingly, the golf course in Radium Hot Springs (west side of the road) is perhaps the most well used part of their winter range. Nonetheless, Parks Canada has been creating more open forest with grasslands, which is an attractive winter range habitat for bighorn sheep, on the east side of the road. This may reduce the dependence of bighorn sheep on the golf course, reduce habituation of sheep to humans, and reduce conflicts between humans and sheep. A further complication is that the bighorn sheep are attracted to the sodium chloride that is deposited on the road during winter (Figure 57). Bighorn sheep are attracted to the road salt on many locations in the Rocky Mountains; bighorn sheep apparently regard sodium chloride as a valuable mineral. Because the bighorn sheep lick road salt from the road, they increase their exposure to traffic (Figure 58). Because the bighorn sheep spent a significant amount of time licking salt from the road, using an alternative for road salt would likely result in a substantial reduction in bighorn sheep-vehicle collisions. However, the problem has been known for at least several years (Osprey Communications, 2005; Dibb, 2006; Preston et al., 2006) and reduction and alternatives to road salt have been suggested in the past (Osprey Communications 2005, Dibb 2006), but this has not resulted in substantial changes in the application of road salt on Mile Hill. Therefore the authors of this report suggest other mitigation measures. An animal detection system may only detect animals in the right-of-way and not on the road (especially break-the-beam systems). Since the bighorn sheep spent substantial time on the actual road, an animal detection system may not be able to provide drivers with reliable warning signals. Therefore the authors of this report suggest a combination of a wildlife fence and a wildlife overpass, or a wildlife underpass as an alternative (Figure 55, Appendix K). Care must be taken to avoid the wildlife fence into a mortality sink for bighorn sheep, similar to a section of the Trans-Canada Highway (Huijser & Paul, 2008). Note that the fence may have to be higher than 2.4 m (8 ft) as bighorn sheep are known to be able to jump very high.

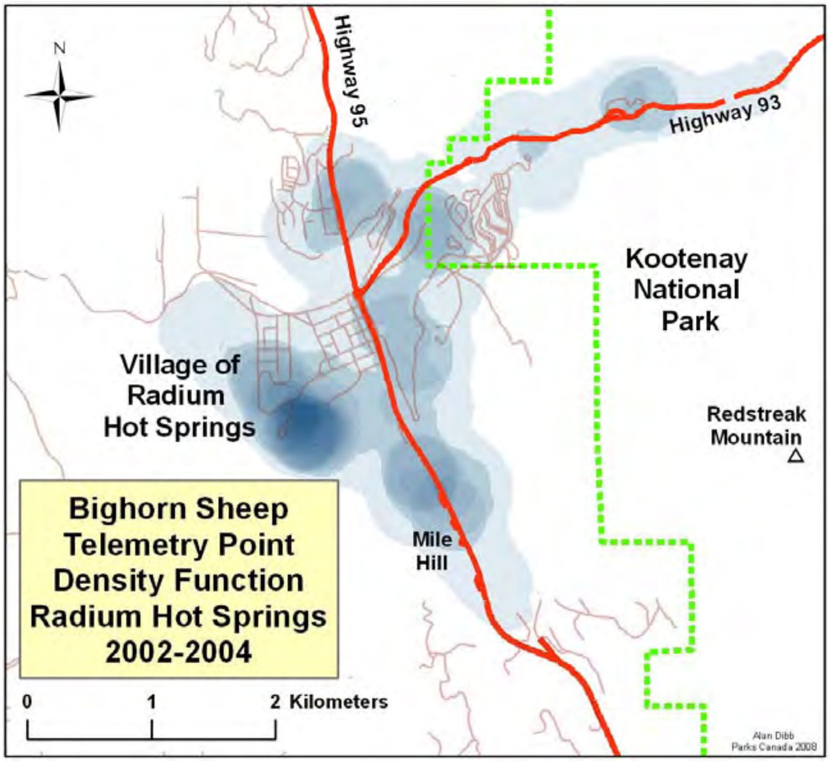

Figure 56. Bighorn sheep habitat use in and around Radium Hot Springs (© Alan Dibb, Parks Canada). The most heavily used area is the golf course on the south western edge of Radium Hot Springs.

Figure 57. Bighorn sheep licking road salt along Hwy 93, on Mile Hill, just south of Radium Hot Springs, British Columbia, Canada (© Marcel Huijser).

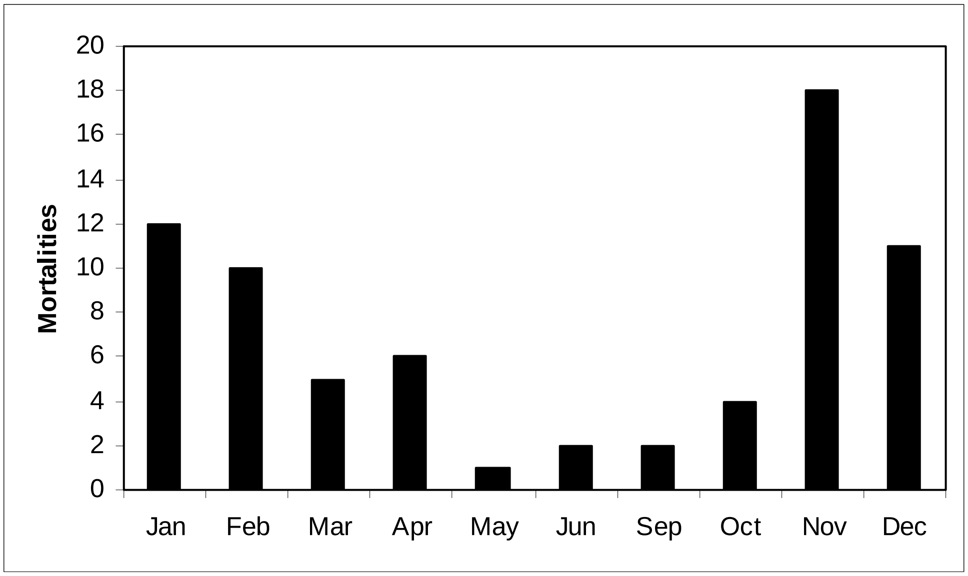

Figure 58. Seasonal distribution of road mortality observations of bighorn sheep in and around Radium Hot Springs (1975- 2007), observed within 100 m Hwy 93S.

A wildlife fence would keep the bighorn sheep from the road, but since the barrier would split their winter range, a crossing opportunity should be considered. Bighorn sheep will continue to be able to cross in the village of Radium Hot Springs, but "forcing" the sheep to cross the road there may increase wildlife-human conflicts in Radium Hot Springs. Little is known about bighorn sheep and their preference for over- and underpasses. However, bighorn sheep are expected to use overpasses (Epps et al. 2005, McKinney & Smith 2007), perhaps more readily than underpasses, but the authors of this report are unaware of actual data that show that bighorn sheep have used overpasses. Nonetheless, bighorn sheep regularly use several wildlife underpasses along the Trans-Canada Highway (Personal Communication, Tony Clevenger, WTI-MSU) (Figure 59), and one underpass (with a road, Hwy 40) under a mining road (coal hauling, Luscar Mine)) Hwy 40 in Alberta (about 9 m wide, 7 m high) (Personal Communication, Beth MacCallum, Bighorn Environmental Design, Hinton, Alberta). The authors of this report propose an overpass at the location where sheep are most frequently seen and hit by vehicles (Figure 55, Appendix K). This overpass may be partially situated on top of one of the three pull-outs on Mile Hill. A wildlife underpass in the draw just north of the pull-out may be considered as an alternative. The wildlife fencing in this area is proposed to start at the edge of Radium Hot Springs (north end) and at the top of Mile Hill at Radium Hill Road. At the fence ends, the fence should preferably be brought as close as possible to the road. However, bighorn sheep may still wander in between the fences by simply walking on the road. It is unknown if and how much of a problem this may be, but additional efforts may be required to discourage this type of behavior, should it occur.

Figure 59. Bighorn sheep using an underpass, and licking minerals, along the Trans-Canada Highway near Canmore, Alberta, Canada. (© Tony Clevenger).

There are two access roads in this road section at 1.1-1.2 km from the Jct in Radium Hot Springs. A wildlife guard (similar to cattle guard) or gates may be installed at these access roads to minimize the chance that bighorn sheep will enter the road corridor and end up in between the fences. The wildlife fence should be provided with wildlife jump-outs at regular intervals to provide an escape for animals that do end up in between the fences after all. Wildlife jump-outs should perhaps be as frequently located as one every 300 m (this would apply to both sides of the road) (Bissonette & Hammer 2000). Since bighorn sheep are known to be able to jump very high, the wildlife jump-outs in this section should also be relatively high. The authors of this report are unaware of species specific guidelines for the height of wildlife jump-outs. Note that large boulders should not be considered as an alternative to wildlife fencing at this location as large boulders are not likely to be a barrier to bighorn sheep.

Since the use of road salt is likely to be continued, bighorn sheep will want to continue to access it. The presence of the fence will direct them to the road sections where the fence ends. Based on their use of the area, the sheep will most likely access the road salt in Radium Hot Springs. While this may increase habituation to humans and may lead to an increase in wildlife-human conflicts, the maximum speed limit is "only" 60 km/h, a speed at which relatively few wildlife-vehicle collisions appear to occur (e.g. Gunther et al. 1998). However, to reduce the likelihood of bighorn sheep focusing on accessing road salt in Radium Hot Springs, the authors of this report propose a drainage system on mile hill that would transport road run-off to the other side of the fence at regular intervals (Figure 60). It may be feasible to do this at a scale where bighorn sheep no longer need to access road salt in Radium Hot Springs or elsewhere. Road salt, and perhaps more importantly other substances in road run-off (e.g. oil, brake fluids, etc), may be damaging to bighorn sheep and other species (e.g. plants, birds) however, and redirecting road run-off to the other side of the fence should be carefully weighed before implemented. Nonetheless, it would basically relocate the existing run-off to the areas on the other side of the fence; it would not change the presence of the substances in the environment and the exposure of animals to it. Alternatively, one may consider spraying “clean” sodium chloride on the “safe” side of the fence at certain times to reduce the likelihood of bighorn sheep being attracted to road salt in Radium Hot Springs. Salt blocks are typically not recommended as it encourages the transmission of diseases, e.g. lung parasites. Note that snow and ice have the potential to block a drainage system, perhaps suggesting hat the drainage system should be open (“gutter”) rather than enclosed (“pipe”).

Should a wildlife underpass be constructed, one may consider installing drainage pipes that would deposit run off from the road, including road salt, inside the wildlife underpass. This phenomenon appears to be present at several, perhaps most, bridge structures in the Rocky Mountains. For example, note that the bighorn sheep in Figure 59 appear to be licking minerals, probably road salt continues to be available through summer when not exposed to precipitation. Such an additional source of sodium chloride at the crossing structure may encourage bighorn sheep in using the structure and it may further reduce the incentive for bighorn sheep to go to the fence ends to lick road salt.

A wildlife fence affects landscape aesthetics and also hinders human movements. That is why the fence on Mile Hill ends at the edge of Radium Hot Springs. However, the pull-outs on Mile Hill (two or three depending on whether one of the pull-outs will make way to a wildlife overpass) serve as lookouts across the valley for humans. Here, the wildlife fence may be placed further down slope so that the visual experience is not affected.

Another potential mitigation measure is to fence the entire road section, and have the fence go around the village of Radium Hot Springs, denying the bighorn sheep access to unnatural food sources (road salt, golf course) altogether. This would also reduce wildlife-human conflicts. On the other hand, this would also keep a portion of the herd from using lambing areas on the west side of the valley (Personal Communication, Alan Dibb, Parks Canada), and it would also block dispersal movements in that direction.

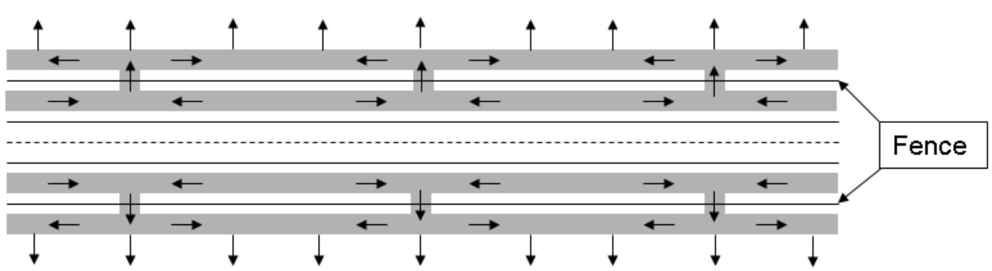

Figure 60. Schematic representation of a potential drainage system for road run off that would transport road salt to the side of the fence where bighorn sheep could access the road salt without being exposed to traffic.

7.4.2.2 North of the Jct Hwy93/95

There is a concentration of bighorn sheep-vehicle accidents just between 200-500 m north of the Jct of Hwy 93/95. Here, sheep are thought to travel up the hill and road bed on the west side of the road (there is a fill slope for the road here) (Figure 61). Once the bighorn sheep reach the road, they jump across the concrete barriers into traffic. The authors of this report propose an animal detection system for this location in order to warn drivers when bighorn sheep are about to jump across the concrete barriers (Figure 55, Appendix K). Animal detection systems should be considered experimental though rather than a proven mitigation measure with a robust estimate of its effectiveness in reducing wildlife-vehicle collisions. Therefore the authors of this report provide an alternative solution: a combination of a wildlife fence and a large mammal underpass (Appendix K). The fence is relatively short and meant to direct bighorn sheep towards the underpass. The fence can be placed a little down on the fill slope so that the fence would not be visible from the road, and the road goes through a cut north of the fill slope, also limiting how a fence would affect landscape aesthetics.

Figure 61. The road section just north of Jct Hwy 93/95 in Radium Hot Springs, looking south. The bighorn sheep appear to travel up the slope, coming from the right, and then surprise drivers as they jump across the fence and concrete barriers into the travel lanes (© Marcel Huijser).

8. COSTS AND BENEFITS

8.1 Introduction

This chapter summarizes the costs of wildlife-vehicle collisions (WVCs), the costs of the suggested mitigation measures, the projected benefits of these mitigation measures, and strategies to reduce the costs, especially with regard to the number of safe crossing opportunities.

8.2 Costs of Wildlife-Vehicle Collisions

There are substantial costs associated with WVCs. Recent research (Huijser et al. 2007b) estimated the average cost for each deer, elk, and moose collision at US$8,015, US$17,475 and US$28,600 respectively. The estimates include costs associated with vehicle repair, human injuries, human fatalities, towing, accident attendance and investigation, hunting and recreational value of the animal concerned, and carcass removal and disposal.

8.3 Costs of Mitigation Measures

Huijser and Paul (2008) provided examples of costs of different types of mitigation measures. This section summarizes cost information for the types of mitigation measures recommended for implementation for the roads in the study area (Table 24), supplemented with additional information. Wildlife over- and underpasses are estimated to be about 20 m long (= road width) in order to be able to cover two vehicle lanes and some road shoulder.

Note that the estimated costs for the mitigation measures (Table 24) are indicative only. Prices of construction materials and fuel have increased substantially over the past years and may continue to rise at a much greater rate than inflation. Furthermore, actual costs are also influenced by the local conditions (e.g. soil, hydrology, dirt and rock transport), and which costs are and are not labeled as directly associated with the mitigation measure. For example, if mitigation measures are implemented at the same time as major road reconstruction, certain costs may be part of the overall road reconstruction rather than specifically because of the construction of safe crossing opportunities.

Table 24. Indicative cost estimates for mitigation measures on or along a 2-lane road (structures are estimated to be about 20 m long (= road width)). Bring fence close to road at crossing structures.

Mitigation measure	Dimensions (as seen by the animals)	Indicative cost estimate (in 2008 Can$)	Comments
Wildlife fencing	2.4 m high	Can$75 per m	Costs may vary based on soil type and replacing wood posts with steel posts. Price includes buried apron.
Wildlife jump-out	About 2 m high	Can$8,000	
Wildlife overpass	50 m wide	Can$2,000,000	Actual cost may vary greatly depending on soil, hydrology and prices of material.
Open span bridge	12 m wide, ≥5 m high	Can$700,000	Actual cost may vary greatly depending on soil, hydrology and prices of material.
Large mammal underpass	7-8 m wide, 4-5 m high	Can$250,000	Actual cost may vary greatly depending on soil, hydrology and prices of material.
Medium mammal underpasses	0.8-3 m wide, 0.5-2.5 m high	Can$70,000	Actual cost may vary greatly depending prices of material.
Small-medium mammal pipes	0.3-0.6 m in diameter	Can$20,000	Depending on the soil and the roadbed, these pipes may be drilled underneath the road without breaking up the road.
Animal Detection system	n/a	Can$15,000-20,000 for 100 m or Can$40,000-200,000 for 1 km	Costs greatly depend on the technology and the road length (e.g. at gap in fence or over longer distances).

These indicative cost estimates were based on the following examples from similar projects:

8.3.1 Wildlife Fencing

Fencing along the western end of the Trans-Canada Highway in Banff National Park (Phase 3-B) (2006-2007) was estimated at Can$75 per meter of fencing (Personal Communication, Terry McGuire, Parks Canada). This fence was 2.4 m high, had wooden posts (pressure treated), and a dig barrier. The fence had smaller mesh at the bottom (16 cm wide, 10 cm high) and bigger mesh towards the top (16 cm wide x 16 high). The dig barrier consisted of buried apron (1 m wide chain link, 5x5 cm mesh) that stuck about 30 cm above ground. The rest of the apron (about 60-70 cm) was buried at a 45° angle away from the fence.

The cost of wildlife fencing along US Highway 93 on the Flathead Reservation in Montana, USA, varied depending on the road section concerned: US$26, US$38, US$41 per meter (2006 prices) (Personal Communication, Pat Basting, Montana Department of Transportation). A finer mesh fence was dug into the soil and attached to the wildlife fence for some fence sections at a cost of US$12 per meter.

8.3.2 Wildlife Jump-outs

Reported costs for one jump-out include US$11,000 (Bissonette & Hammer 2000) and US$6,250 (Personal Communication, Pat Basting, Montana Department of Transportation).

8.3.3 Wildlife Overpasses

Wildlife overpasses across the 4-lane Trans-Canada Highway in Banff National Park (Phase 3-A) were estimated at Can$1.75 million each (1995-1997) (Personal Communication, Terry McGuire, Parks Canada). The overpasses were 52 m wide and 70 m long (across four lanes of traffic). In 2007, based on the construction on the Trans-Canada Highway in the Lake Louise area, the costs for a 60 m wide overpass across a two lane road was estimated at Can$3.500,000-Can$4,000,000, including traffic control and detour (Personal Communication, Terry McGuire, Parks Canada).

A proposed overpass across Montana Highway 83 near Salmon Lake (two-lane road) was estimated to cost US$1,500,000 - US$2,400,000 in 2006 (Personal Communication, Pat Basting, Montana Department of Transportation).

The costs for six wildlife overpasses (30-50 m wide) across 4 lane roads in The Netherlands ranged between €3,500.000 and €14,7500,000 (costs in 2004-2006 Euros) (Table 25).

Overpasses that are 50-70 m wide are used by a wide variety of species. Data are limited, but the available data suggest that the number of species that use an overpass increases strongly with increasing width of an overpass, and this increase starts to level off between 50-70 m (Pfister et al. 2002). Aquatic or semi-aquatic species may not benefit from a wildlife overpass, although many overpasses have ponds on either side and the overpass “Groene Woud” in The Netherlands also has a water pump to create wet habitat across the entire length of the overpass (Table 25).

Table 25. Characteristics of wildlife overpasses in The Netherlands. * = cost in year of completion (Partially based on Kruidering et al. 2005 and Personal Communication, Hans Bekker, Ministerie van Verkeer en Waterstaat, The Netherlands).

Name wildlife overpass	(Rail)road and nearby towns	Dimensions	Costs (in 2004 Euros)	Year com-pleted	Comments
Terlet	A50, between Arnhem and Apeldoorn	50 m wide, 95 m long	€3,600,000	1988	Across a 4-lane motorway and a frontage road. Pond on the east side of the overpass.
Woeste Hoeve	A50 between Arnhem and Apeldoorn	45 m wide, 140 m long	€3,600,000	1988	Across a 4-lane motorway and a frontage road.
Boerskotten	A1, near Oldenzaal	Hourglass shape, 15 m wide in middle of span, 80 m long	€1,400,000	1992	Across a 4-lane motorway.
Harm van de Veen	A1, near Kootwijk, between Amersfoort and Apeldoorn	Hourglass shape, 80 meters wide at each end, 30 meters wide in middle of span	€3,600,000	1998	Across a 4-lane motorway. Pond on the north side of the overpass.
De Borkeld	A1, near Rijssen	Hourglass shape, 30 meters wide at each end, 16 meters wide in middle of span, 51.6 meter long	€3.800.000	2003	Across a 4-lane motorway. Pond on the south side of the overpass.
Slabroek	A50, between Uden and Nistelrode	15 m wide	€5,600,000	2003	Combined with pedestrian/ bicycle path. Across a 4-lane motorway and a frontage road
Leusderheide	A28 between Amersfoort and Zeist	48 m wide, 46 m long	€3,500,000	2005	Across a 4-lane motorway
Groene Woud	A2 between Boxtel and Best	52 m wide	€9,100,000*	2005	With wet zone, including a water pump and ponds on both sides of the overpass. Across a 4-lane motorway and a frontage road
No name	N297, between Nieuwstadt and Sittard	3 m wide, 42 m long	€290,000*	2005	A combination of an overpass and a badger tunnel (40 cm diameter), buried inside the overpass as the 4 lane road was constructed in a trench
Crailoo	Naarderweg (N524) and railroad between Hilversum and Bussum	50 m wide, 800 m long, 2 bridges and several sections of fill	€14,750,000*	2006	Combined with pedestrian/bicycle path. Ponds on both sides of the overpass. Across a 2-lane road, a railroad, a railroad yard, and sport fields.
Waterloo	A73, near Beesel	40 m wide, 100 m long	€2,400,000	2007	Combined with pedestrian path. Across a 4-lane motorway. Construction costs were part of larger project

8.3.4 Open Span Bridges

An open span bridge along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA, (across Jocko River seasonal side canal) measured 30 m in width (road width) and 12 m in length (road length). Because of slopes the effective width of the underpass was less than 12 m. The costs are estimated at US$423,483 in 2006 (Personal Communication, Pat Basting, Montana Department of Transportation).

Underpasses under open span bridges across along the 4-lane Trans-Canada Highway in Banff National Park (Phase 3-A) measure about 12 m in width and about 5 m in height. Costs were estimated between Can$700,000-1,000,000 (1995-1997) (Personal Communication, Terry McGuire, Parks Canada). In 2007, based on the construction on the Trans-Canada Highway in the Lake Louise area, the costs for a 16 to 25 m wide underpass structure across a 2 lane road, including traffic control and detour, was estimated at Can$2,500,000 (Personal Communication, Terry McGuire, Parks Canada)

8.3.5 Large Mammal Underpasses

Here, we define large mammal underpasses as structures that are not bridges, but e.g. box culverts or arched culverts that are at least 7-8 m wide and 4-5 m high.

Large mammal underpasses along the 4-lane Trans-Canada Highway in Banff National Park (Phase 3-A) measure about 7 m in width and 4 m in height. Costs were estimated between Can$ 225,000-250,000 (1995-1997) (Personal Communication, Terry Mcguire, Parks Canada).

Three large mammal wildlife underpasses, all arched culverts along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA, (south of Ravalli) measure about 7-8 m in width and about 5 m in height. The length (road width) varies between 18.3 and 21.9 m). The costs were estimated at about US$217,000 each in 2006 (Personal Communication, Pat Basting, Montana Department of Transportation).

In The Netherlands, large mammal underpasses (7-10 m wide, about 4 m high) were estimated at €30,000 - €50,000 per m (road width) (Kruidering et al. 2005). Assuming a road width of 20 m the costs were €600,000-1,000,000.

8.3.6 Medium Mammal Underpasses

Here, medium mammal underpasses are defined as box culverts or culverts that are between 0.8 and 3 m wide, and 0.5-2.5 m high.

Medium mammal box culverts under the 4-lane Trans-Canada Highway in Banff National Park (Phase 3-A) measure about 3 m in width and 2.5 m in height. Costs were estimated at about Can$ 180,000 (1995-1997) (Personal Communication, Terry Mcguire, Parks Canada). In 2007, based on the construction on the Trans-Canada Highway in the Lake Louise area, the costs for a box or elliptical culvert 3-4 m wide and high across a two lane road were estimated at approximately Can$1,000,000 including traffic control and detour (Personal Communication, Terry Mcguire, Parks Canada).

Two medium mammal box culverts (1.2-1.8 m wide, 1.2-1.8 m high, 27.5 m long) and one medium mammal culvert (about 2 m wide, 1.5 m high, 27.5 m long) along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA, (south of Ravalli) were estimated at about US$69,000 each in 2006 (Personal Communication, Pat Basting, Montana Department of Transportation).

In The Netherlands, medium mammal box culverts (0.8-1.3 m wide, 0.5-0.75 m high) were estimated at €1,200-2,500 per m (road width) (Kruidering et al. 2005). Assuming a road width of 20 m the costs were €24,000-50,000.

8.3.7 Small-Medium Mammal Pipes

Here we define small-medium mammal pipes as pipes that measure about 0.3-0.6 m in diameter.

In The Netherlands, small-medium mammal pipes (“badger pipes”, 0.6 m in diameter) were estimates at €700-1,200/m (Kruidering et al., 1995). Assuming a road width of 20 m the costs were €14,000-24,000.

8.4 Effectiveness of Mitigation Measures

Wildlife fencing in combination with wildlife overpasses and underpasses as well as animal detection systems appear to reduce collisions with large mammals substantially (Table 26). Note that the estimate for the effectiveness of wildlife fencing in combination with wildlife overpasses and underpasses is much more robust than that for animal detection systems. Additional studies on the effectiveness of animal detection systems may cause substantial corrections (upwards or downwards) with regard to their effectiveness estimate.

Table 26. Effectiveness of mitigation measures in reducing collisions with large mammals (deer and larger).

Mitigation measure	Reduction in collisions with large mammals	Sources
Wildlife fencing in combination with wildlife overpasses and underpasses	87%	78.5% (Reed et al. 1982), 80% (Lavsund and Sandegren 1991), 80% Clevenger et al. (2002), >90% (Ward 1982), 94-97% (Woods 1990), 97-99% (Sielecki 1999)
Animal detection systems	87%	82% (review in Huijser et al. 2006), 92% (Norris & Gagnon 2008).

8.5 Quantity and Costs of Proposed Mitigation Measures

Table 27 provides a summary of the quantity and indicative costs for the proposed mitigation measures in the study area. The proposed mitigation measures in Kootenay and Banff National Park are estimated at Can$20,920,000 (indicative cost estimate) based on the costs specified in Table 27 only. The proposed mitigation measures in and around Radium Hot Springs are estimated at Can$2,440,000 (indicative cost estimate) based on the costs specified in Table 27 only. About half of the costs of the mitigation measures are based on wildlife fencing, and the other half are based on safe crossing opportunities for wildlife.

Table 27. Home range size and diameter estimates for other species seen inside the mitigation zones. The estimates relate to female individuals where possible, and local or regional data weighed heavily in the final estimation of the home range size.

Road section	Mitigation measure	Indicative cost estimate per unit	Total indicative costs
Kootenay /Banff	2*61.8 km Wildlife fence	Can$75 per m	Can$9,270,000
	?? wildlife guards or gates for access roads	?	?
	?? wildlife jump-outs	Can$8,000	?
	3 Wildlife overpasses (one is an existing road tunnel (Figure 62), minimal extra costs)	Can$2,000,000	Can$4,000,000
	5 over span bridges (3 of them are existing bridges (Figure 63 through 65), minimal extra costs)	Can$700,000	Can$1,400,000
	25 Large mammal underpasses	Can$250,000	Can$6,250,000
	?? medium mammal underpasses	Can$70,000	?
	?? small-medium mammal pipes	Can$20,000	?
Radium Hot Springs	2*2.8km Wildlife fence	Can$75 per m	Can$420,000
	?? wildlife guards or gates for access roads	?	?
	?? wildlife jump-outs	Can$8,000	?
	Road run-off drainage system	?	?
	1 wildlife overpass	Can$2,000,000	Can$2,000,000
	?? medium mammal underpasses	Can$70,000	?
	?? small-medium mammal pipes	Can$20,000	?
	300 m animal detection system	Can$20,000	Can$20,000

Figure 62. The existing overpass (road tunnel) just east of the hot spring pools near Radium Hot Springs (© Marcel Huijser).

Figure 63. The bridge across the Kootenay River at Kootenay Crossing (© Marcel Huijser).

Figure 64. The bridge across Wardle Creek (© Marcel Huijser).

Figure 65. The bridge across the Vermilion River at Vermilion Crossing (© Marcel Huijser).

8.6 Costs and Benefits of Mitigation Measures

The length of the mitigation zones in Kootenay and Banff National Park is 60.3% of the total road length while 79.7% of all reported road mortalities fall within these mitigation zones (Table 28). The length of the mitigation zones in and around Radium Hot Springs is 37.4% of the total road length while 83.1% of all reported bighorn sheep road mortalities fall within these mitigation zones (Table 28).

Table 28. The length of the mitigation zones in relation to the number of reported wildlife road mortalities (all species) in those mitigation zones, based on 33 years or data and observations within 100 m from the road. * = bighorn sheep only.

Road section	Total Road Length (km)	Length Mitigation Zones (km)	Length Mitigation Zones (%)	Number of Reported Road Mortalities along Entire road section (N)	Number of Reported Road Mortalities in Mitigation Zones (N)	Percentage of Road Mortalities in Mitigation Zones (%)
Kootenay/Banff	102.9	62.1	60.3	1206	961	79.7
Radium Hot Springs	9.1	3.4	37.4	71*	59*	83.1*

The total number of reported road mortalities of large mammal species has increased in Kootenay and Banff National Park between 1998 and 2007 (Figure 66). The same is true for bighorn sheep road mortalities in and around Radium Hot Springs, but mortality has been slightly lower in 2006 and 2007 compared to 2005 (Figure 66).

Assuming a total cost of Can$20,920,000 for the mitigation measures in Kootenay and Banff National Park (Table 27), and assuming a life span of 25 years for wildlife fencing (Can$370,800 per year) and 75 years for wildlife underpasses and overpasses (Can$155,333 per year), the total costs of the mitigation measures are Can$526,133 per year, ignoring maintenance and discounting. Assuming an average of Can$10,000 in costs to society for a collision with a large animal (see section 8.2), preventing about 53 collisions with large animals per year would make the costs of the mitigation measures equal to the benefits. For the mitigated road sections in Kootenay and Banff National Park, the reported number of collisions with large animals has been about 50 per year in recent years, and, assuming a reduction of 87%, the mitigation measures may prevent about 44 collisions with large animals per year, relatively close to the break-even point.

Assuming a total cost of Can$2,440,000 for the mitigation measures in and around Radium Hot Springs (Table 27), and assuming a life span of 25 years for wildlife fencing (Can$16,800 per year), 75 years for wildlife underpasses and overpasses (Can$26,666 per year), and 10 years for an animal detection system (Can$2,000 per year), the total costs of the mitigation measures are Can$45,466 per year, ignoring maintenance and discounting. Assuming an average of Can$10,000 in costs to society for a collision with a large animal such as bighorn sheep (see section 8.2), preventing 4 collisions with large animals per year would make the costs of the mitigation measures equal to the benefits. For the mitigated road sections in and around Radium

Hot Springs, the reported number of collisions with large animals has been about 10 per year in recent years, and, assuming a reduction of 87%, the mitigation measures may prevent 9 collisions with bighorn sheep per year, substantially more than the break-even point.

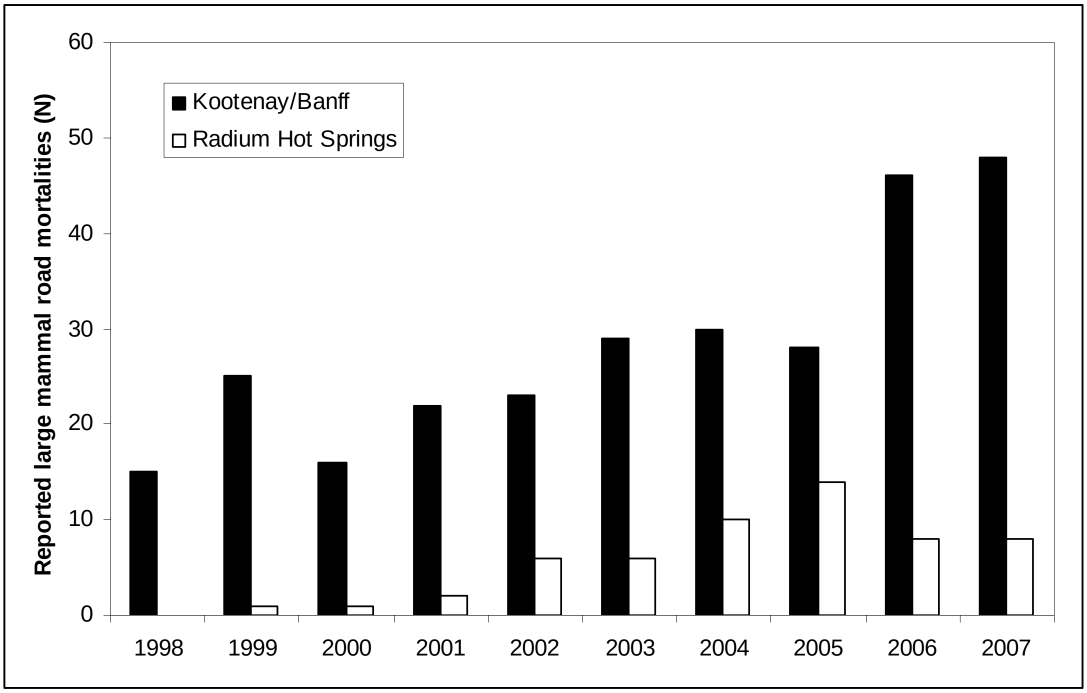

Figure 66. Number of reported large mammal road mortalities, observed within 100 m from road, in the mitigation zones in Kootenay/Banff and in and around Radium Hot Springs between 1998 and 2007. The large mammal species in the Kootenay/Banff section include deer, white-tailed deer, mule deer, elk, moose, bighorn sheep, black bear, while the sections in and around Radium Hot Springs relate to bighorn sheep only.

8.7 Alternative Mitigation Measure Configurations and Costs

There are an infinite number of possible configurations of possible mitigation measures. Rather than trying to formulate different packages relating to different management goals and ambitions, the authors of this report prefer to allow the users of this report to compile their own configuration. Most likely, the users of this report are interested in finding configurations that would be less expensive than the one proposed by the researchers. This section shows different strategies of how costs may be reduced, and which data, or tools, should be used when compiling an alternative configuration of mitigation measures.

8.7.1 Shorter Sections of Wildlife Fencing

Wildlife fencing represents about half the costs of the proposed mitigation measures (Table 27). Therefore, shorter mitigation zones and shorter road sections with wildlife fencing can lead to substantial cost reductions. The researchers have ranked the 10 year mortality clusters (Chapter

4, Table 10, 11), allowing the users of this report to prioritize locations or phase the implementation of mitigation measures. Obviously, shorter mitigation zones have direct implications for where wildlife-vehicle collisions are addressed and where they are allowed to continue. The ranking of the 10 year mortality clusters however, does ensure that the users can apply the funds first to the most severe road sections. When identifying and prioritizing the mortality clusters, all species in Table 2 were weighed equally. Should more emphasis be required on, for example, the largest species or species that are of greatest conservation concern, new analyses with new selections and perhaps weighing factors are required. Another consideration when shortening mitigation zones and shorter road sections with wildlife fencing is that, especially in the Kootenay Valley, fence end runs may occur, especially for species that appear to be dependent on the vegetation in the right-of-way (e.g. white-tailed deer, elk). In the Kootenay Valley, mitigation zones that are relatively short may change the location of animal-vehicle collisions, especially with white-tailed deer and elk, rather than reduce them.

8.7.2 Fewer Crossing Opportunities

The proposed number of safe crossing opportunities is based on the diameter of the home range (Table 18, 19 and 20) of the species that have been observed on and alongside the road, and the presence and length of wildlife observation clusters (Table 17, Figure 21). The distance between large mammal crossing opportunities is strongly influenced by the large mammal species that has the smallest home range size: white-tailed deer. One could argue that white-tailed deer are an invasive species in this area and that their conservation status is relatively low. Therefore one could argue that the diameter of the home range for white-tailed deer should not be influencing the number of large mammal crossing opportunities very strongly. In areas where both white-tailed deer and mule deer occur, but only habitat connectivity for mule deer is a concern, this could increase the distance between large mammal crossing opportunities from about 1 km to about 2 km (Table 19). Similarly, in areas where both white-tailed deer and bighorn sheep occur, but only habitat connectivity for bighorn sheep is a concern, this could increase the distance between large mammal crossing opportunities from about 1 km to about 3 km (Table 19). While the same rationale applies to other species, there is a limit to using this rationale to calculate how many (or how few) crossing opportunities should be provided for. For example, if one would only be concerned about habitat connectivity for grizzly bear, the distance between safe crossing opportunities would be about 18 km (Table 20); a distance that many experts are likely to agree is substantially too far. This example also illustrates that using the diameter of species' home ranges is not necessarily an "overly conservative or safe measure". It is a useful tool based on clear parameters and allows for consistent treatment of different species, but it does not necessarily guarantee sufficient habitat connectivity and viable populations. One could also argue that wildlife observation clusters with higher numbers of observations are more important than wildlife observation clusters with lower numbers of wildlife observations (see ranking values in table 17). On the other hand, wildlife observation clusters are already a way to focus on areas with a relatively high concentration of wildlife on or close to the road.

8.7.3 Less Expensive Crossing Opportunities

Choosing a different type of safe crossing opportunity may reduce costs. For example, a wildlife overpass is substantially more expensive that an over span bridge or a large mammal underpass (Table 24). However, certain species, e.g. grizzly bear, have a strong preference for wildlife overpasses (Table 23, Clevenger et al. 2002). While ungulates such as deer and elk use large mammal underpasses in large numbers, wildlife overpasses are used substantially more by these species. On the other hand, using a type of crossing structure that is not optimal for the species concerned, or using a crossing structure that has smaller dimensions than recommended does not necessarily mean that such alternative structures will not be used by the target species, except if a species is larger than the dimensions of the crossing structure, which makes use physically impossible. Using a different type or smaller dimensions for a crossing structure are likely to reduce the use by the target species though. There is variation between large mammals. For example, Gordon and Anderson (2003) found that migratory mule deer minimally need an underpass for a 2 lane road to be about 6 m wide and about 2.4 m high, while larger structures are recommended for elk or moose. On the other hand, one could argue that one should strive for ecosystem connectivity rather than focusing on one or a few selected species. Reducing the number, type and size of crossing opportunities to the absolute minimum to what we think is needed for a few selected species may ignore the needs of other species or ignore ecosystem processes.

9. WHERE TO START AND HOW?

9.1 Introduction

The suggested mitigation measures relate to long sections of road, and the associated costs, not withstanding the benefits, are substantial. Section 8.7 described the data and tools that may be used when compiling alternative configurations of mitigation measures. This chapter provides a rationale for where and how to start with the implementation of the mitigation measures.

9.2 Kootenay and Banff National Park

The 10 year mortality clusters (Figure 19) were ranked based on the number of reported road mortalities per 100 m road length (Table 13). However, in addition to the ranking value of a cluster, the absolute length of the cluster and the distance to the next cluster should be considered when deciding where to start with the implementation of the mitigation measures, as short sections of fencing may result in fence end runs by certain species, and longer sections of fencing are likely to be more effective in reducing WVCs. The highest ranking cluster (26.3-26.8) is relatively short and its neighboring clusters (27.1-27.5) and (25.6-25.9), while close, rank 5th and 6th respectively. The second highest ranking cluster (40.0-42.6) is substantial in length and its neighboring clusters to the south (36.7-37.8) and (32.4-36.6), while 2.2 km away, rank 3rd and 4th. When the small gap (100 m) between these two neighboring clusters is ignored, there is a substantial concentration of high ranking clusters between 32.4 and 42.6. In addition, this is an area where Hwy 93S starts to cross the Kootenay Valley (rather than paralleling it on the foot of the western ridge) and the area has a concentration of wildlife observation clusters (Figure 21).

White-tailed deer are the most frequently reported road killed species (83-100%) in the three clusters in the point 32.4-42.6 km road section. This is an added benefit as it is the species that has the smallest home range size of the large mammal species investigated (Table 19). The diameter of the home range of white-tailed deer is about 1 km, thus 1 km buffer zones should be provided on each side of a mortality cluster to reduce the probability of fence end runs. However, at Kootenay Crossing (point 42.7), the fence end can be tied in with the southern end of the bridge across the Kootenay River. It is important though that large mammals are provided a dry path (≥2 m wide), cleared of large rocks under the bridge (see Figure 63), preferably on the south bank. A dry path may not be feasible when water levels are high in spring and early summer, and large rocks may need to be removed every summer after water levels have dropped. Perhaps that a ledge for large mammals can be constructed just above the high water line that does not constrict the river too much.

Note that the 1 km buffer zone on either side of a mortality cluster is based on the assumption that the home range of white-tailed deer is circular. However, because of the suspected dependence on the grass-herb vegetation in the right-of-way, white-tailed deer home ranges may be elongated alongside the road corridor, suggesting that longer buffer zones may be considered. However, no data are available with regard to this issue.

Having a phased approach to the implementation of the mitigation measures may not only be necessary because of funding availability, but it may also have biological benefits. Wildlife would have time to adjust to the fencing and gradually increase their use of the safe crossing opportunities, adjust to alternative forage locations (especially white-tailed deer and elk), including to switching to grasses and herbs in burned locations, including the proposed management burns in the Kootenay Valley (see Figure 54).

In the next two sections we describe two options for mitigation measure: one based on wildlife fencing with animal detection systems in fence gaps and an existing bridge (across the Kootenay River), and one based on wildlife fencing in combination with underpasses for large mammals and an existing bridge (across the Kootenay River).

9.2.1 Option 1: Animal Detection Systems

This option has the lowest construction costs, but must be considered experimental. In addition, it will most likely require considerable effort with regard to operation and maintenance and should be accompanied with research that investigates the reliability of the animal detection system, whether animals (especially white-tailed deer and elk) are sufficiently discouraged from wandering off in the right-of-way in between the fences (fence end close to road with median barrier and electric mat across the road), and the effectiveness in reducing collisions with large mammals. The operation and maintenance efforts will most likely include regular checks on the operational status of the animal detection system and potential repairs, mowing of the right-of-way in the detection areas of the animal detection systems, and potential "hazing" of animals that may have ended up in between the fences.

The authors of this report advise Parks Canada to start with providing a dry path, cleared of large rocks, preferably on the south bank, under the bridge across the Kootenay River. Depending on whether a ledge needs to be constructed, this may cost a few hundred to several tens of thousands of Can$. If the existing bridge does not allow for a dry path, cleared of large rocks for large mammals, one may consider the following options:

- Accept that the bridge across the Kootenay River does not function as a large mammal underpass and force animals that followed the fence from south to north to cross the Kootenay River and then cross the road north of the Kootenay River. It is advisable to provide an electric mat across the road at the north end of the bridge to discourage animals from crossing the bridge by walking on the road and wandering off in between the fences. The installation of this matt would be part of the second phase (see below).
- Leave a gap between the fence (see below) and the south bank of the Kootenay River (e.g. 100 m gap) and install an animal detection system (see below) at this gap and an electric mat across the road at the fence end. The installation of the fence, animal detection system and electric mat would be part of the second phase (see below).

The second phase of the project would involve the installation of a wildlife fence in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The north end of the fence should be tied in with the south bank of the Kootenay River, or should be about 100 m from the south bank, leaving a gap between the north end of the fence and the south bank of about 100 m (see bullets above). This fence should then extent southwards until the first crossing opportunity. If the distance between safe crossing opportunities is based on the home range of large mammal species, especially the species that is most frequently killed on the road and seen alongside the road (alive) in this area, then the first crossing opportunity should be located about 1 km (e.g. between point 41.5 and 41.8) from the south bank of the Kootenay River. The costs for fencing are estimated at 2 * 1000 m * Can$ 75 = Can$ 150,000. The fence should be brought close to the road, potentially in combination with a boulder field or concrete barriers along the road side. In addition, an electric mat across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences. An electric matt should also be provided across the road at the north bank of the Kootenay River (see bullets above) (2 * Can$ 125/m * 7.3 m = Can$ 1,825). Finally, wildlife jump-outs should be provided for. The authors of this report advise 10 wildlife jump-outs (5 on each side of the road, 10 * Can$ 8,000 = Can$ 80,000. The jump-outs should be provided immediately adjacent to a gap in the fence or fence end, at 100 m from the first jump-out, and in the middle of the 1 km fenced road section. The total costs for the second phase are estimated at Can$231,825.

The third phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 4th phase). The gap should be between 30-100 m wide. An animal detection system would have to cover two gaps, one on each side of the road. An animal detection system for these two sides of the road is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the third phase are estimated at Can$35,000. Note that the animal detection systems would only cover the first 30-100 m from the south end of the fence, and that no warnings are provided to drivers for animals crossing further south.

The fourth phase of the project would involve the installation of about 1 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 40.5 and 40.8. Fencing costs are estimated at Can$ 150,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can$ 1,825). Finally, wildlife jump-outs should be provided for (10 * Can$ 8,000 = Can$ 80,000). The total costs for the fourth phase are estimated at Can$231,825.

The fifth phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 6th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The sixth phase of the project would involve the installation of about 1.4 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 38.9 and 39.3. Fencing costs are estimated at Can$ 210,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can $ 1,825). Finally, wildlife jump-outs should be provided for (12 * Can$ 8,000 = Can$ 96,000). The total costs for the fourth phase are estimated at Can$307,825.

The seventh phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 8th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The eighth phase of the project would involve the installation of about 2.0 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 37.1 and 37.5. Fencing costs are estimated at Can$ 300,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can$ 1,825). Finally, wildlife jump-outs should be provided for (18 * Can$ 8,000 = Can$ 144,000). The total costs for the fourth phase are estimated at Can$345,825.

The ninth phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 10th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The tenth phase of the project would involve the installation of about 1.0 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 36.2 and 36.4. Fencing costs are estimated at Can$ 150,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can$ 1,825). Finally, wildlife jump-outs should be provided for (10 * Can$ 8,000 = Can$ 80,000). The total costs for the fourth phase are estimated at Can$231,825.

The 11th phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 12th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The 12th phase of the project would involve the installation of about 1.0 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 35.2 and 35.4. Fencing costs are estimated at Can$ 150,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can$ 1,825). Finally, wildlife jump-outs should be provided for (10 * Can$ 8,000 = Can$ 80,000). The total costs for the fourth phase are estimated at Can$231,825.

The 13th phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 14th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The 14th phase of the project would involve the installation of about 1.0 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 34.0 and 34.3. Fencing costs are estimated at Can$ 150,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can $ 1,825). Finally, wildlife jump-outs should be provided for (10 * Can$ 8,000 = Can$ 80,000). The total costs for the fourth phase are estimated at Can$231,825.

The 15th phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 16th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The 16th phase of the project would involve the installation of about 1.2 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should allow for a second at grade crossing opportunity between point 32.6 and 32.9. Fencing costs are estimated at Can$ 180,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can$ 1,825). Finally, wildlife jump-outs should be provided for (12 * Can$ 8,000 = Can$ 96,000). The total costs for the fourth phase are estimated at Can$277,825.

The 17th phase of the project would involve the installation of an animal detection system at the south end of the fence across the width of the eventual gap (see 18th phase). The gap should be between 30-100 m wide. An animal detection system is estimated at Can$20,000, excluding installation and signage. Installation is estimated at Can$15,000. Signage is estimated at Can$5,000-15,000, depending on the type of sign (e.g. flashing light or variable message sign). The total costs for the fifth phase are estimated at Can$35,000.

The 18th phase of the project would involve the installation of about 1.2 km of wildlife fencing, in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The fence should end about 1 km beyond where the 10 year mortality cluster starts at the south end (south end cluster at 32.4, fence should end at 31.4). Fencing costs are estimated at Can$ 180,000. Both the north and south end of the fence should be brought close to the road, in combination with a boulder field or concrete barriers. In addition, electric mats across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences (Can $ 1,825). Finally, wildlife jump-outs should be provided for (12 * Can$ 8,000 = Can$ 96,000). The total costs for the fourth phase are estimated at Can$277,825.

In addition to the gaps in the fence combined with animal detection systems, one may consider crossing opportunities for medium mammals (section 8.5). Perhaps small reinforced openings (holes) could be provided for at regular intervals that would allow mammals of coyote size and smaller to access the right-of-way and either use jump-outs or openings to exit the road corridor. This approach would be consistent with leaving the roadbed untouched for this mitigation option.

The work can be stopped or delayed after each phase until sufficient funds available for the next phase. The cumulative costs and road length mitigated is plotted in Figure 67.

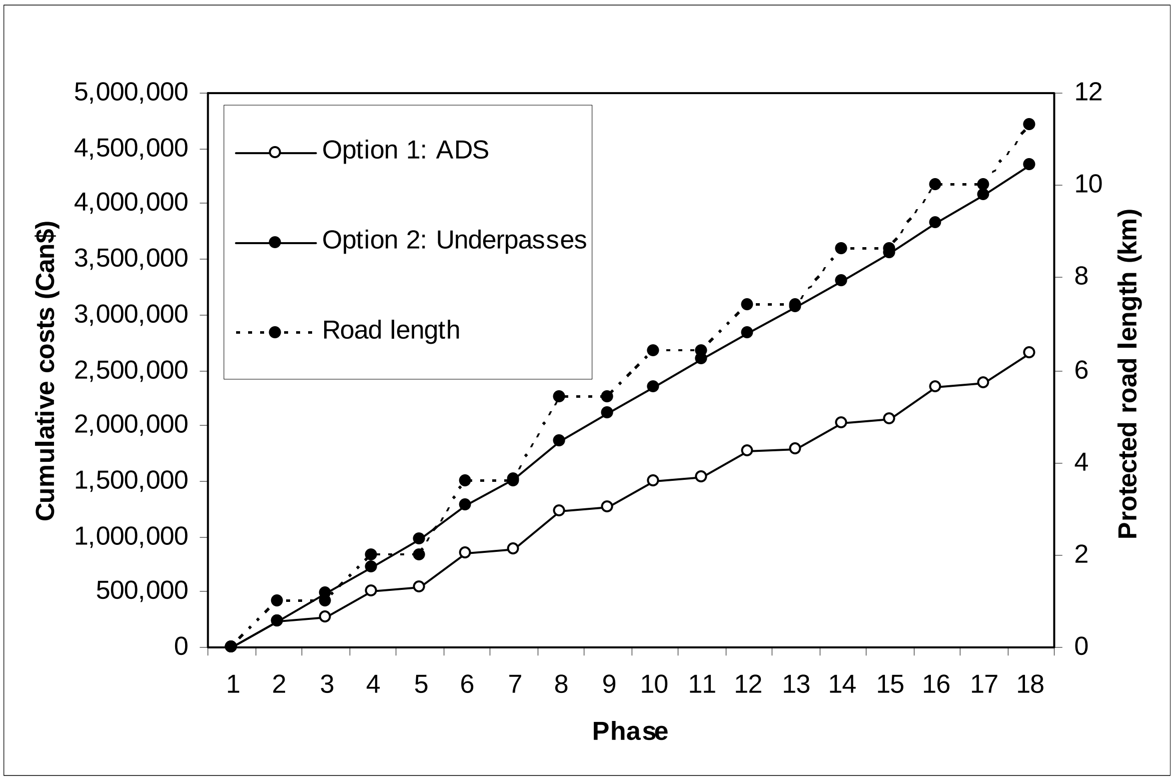

Figure 67. The cumulative costs of the two mitigation options for the road section south of Kootenay Crossing (point 31.4 through 42.7 km). ADS = Animal Detection Systems.

9.2.2 Option 2: Large Mammal Underpasses

This option has the higher construction costs, but requires less operation and maintenance effort, except for periodic inspection and potential repairs to underpasses. Standard monitoring of underpasses and wildlife-vehicle collisions is advised.

The authors of this report advise Parks Canada to start with providing a dry path, cleared of large rocks, preferably on the south bank, under the bridge across the Kootenay River. Depending on whether a ledge needs to be constructed, this may cost a few hundred to several tens of thousands of Can$. If the existing bridge does not allow for a dry path, cleared of large rocks for large mammals, one may consider the following option:

Accept that the bridge across the Kootenay River does not function as a large mammal underpass and force animals that followed the fence from south to north to cross the Kootenay River and then cross the road north of the Kootenay River. It is advisable to provide an electric mat across the road at the north end of the bridge to discourage animals from crossing the bridge by walking on the road and wandering off in between the fences. The installation of this matt would be part of the second phase (see below).

The second phase of the project would involve the installation of a wildlife fence in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The north end of the fence should be tied in with the south bank of the Kootenay River. This fence should then extent southwards until the first crossing opportunity. If the distance between safe crossing opportunities is based on the home range of large mammal species, especially the species that is most frequently killed on the road and seen alongside the road (alive) in this area, then the first crossing opportunity should be located about 1 km (e.g. between point 41.5 and 41.8) from the south bank of the Kootenay River. Note that one should be flexible with regard to the exact location of the underpasses; field verification (when there is no snow on the ground) is required when making the final decision on where the large mammal underpasses should be constructed. The costs for fencing are estimated at 2 * 1000 m * Can$ 75 = Can$ 150,000. In addition, an electric mat across the road should be installed to prevent wildlife from wandering off in the right-of-way in between the fences. An electric matt should also be provided across the road at the north bank of the Kootenay River (see above) (Can $ 1,825). Finally, wildlife jump-outs should be provided for. The authors of this report advise 10 wildlife jump-outs (5 on each side of the road, 10 * Can$ 8,000 = Can$ 80,000. The jump-outs should be provided immediately adjacent to a gap in the fence or fence end, at 100 m from the first jump-out, and in the middle of the 1 km fenced road section. The total costs for the second phase are estimated at Can$231,825.

The third phase of the project would involve the construction of a large mammal underpass at the south end of the fence. A large mammal underpass is estimated at Can$250,000. The electric mat at the south end of the fence would stay in place until the next section of fence is installed. Then the electric mat at the south end would be moved to the “new” south end of the fence. Note that the fence north of the large mammal underpass needs to be tied in with the large mammal underpass.

The fourth phase of the project would involve the installation of about 1 km wildlife fence in combination with fence end treatments (i.e. bring fence close to road and electric mats across road). The north end of the fence should be tied in with the large mammal underpass. This fence should then extent southwards until the next crossing opportunity (e.g. between point 40.5 and 40.8) from the south bank of the Kootenay River. The costs for fencing are estimated at 2 * 1000 m * Can$ 75 = Can$ 150,000. In addition, the electric mat at the south end of the previous wildlife fencing section (phase 2) should be moved to the “new” south end of the fence. Finally, wildlife jump-outs should be provided for. The authors of this report advise 10 wildlife jump-outs (5 on each side of the road, 10 * Can$ 8,000 = Can$ 80,000. The jump-outs should be provided immediately adjacent to a gap in the fence or fence end, at 100 m from the first jump-out, and in the middle of the 1 km fenced road section. The total costs for the second phase are estimated at Can$230,000.

The following phases are similar to the phases described for option 1, with the distinction that animal detection systems are replaced with large mammal underpasses and that there will only be two electric mats across the road: one just north of the bridge across the Kootenay River, and one at the ever moving south end. These differences are also reflected in the costs for the following phases.

In addition to the large mammal underpasses, one may consider crossing opportunities for small-medium mammals (e.g. box culverts and pipes under the road) at regular distances (see section 8.5). This approach would be consistent with physically separating wildlife from traffic for this mitigation option.

The work can be stopped or delayed after each phase until sufficient funds available for the next phase.

9.3 Mile Hill, south of Radium Hot Springs

9.3.1 Option 1: Alternative de-icer

Road salt would no longer be used on any of the roads (at least Hwy 93/95 with high vehicle speeds) in the vicinity of the winter range of the bighorn sheep. The area would have to extend from a couple of km’s north of the Jct in Radium hot springs (e.g. 2-3 km) to about 5 km south of the Jct and e.g. 3 km east of the Jct into Kootenay National Park. Costs would relate to (additional) equipment (trucks, storage facility), the de-icer itself, and other operational resources to be able to apply an alternative de-icer in addition to sodium chloride. The total costs are unknown.

This option is likely to reduce the time that bighorn sheep spend on the road. However, bighorn sheep will still cross the road, most likely to gain access to the grasslands on the golf course in Radium Hot Springs. After monitoring road mortality under the new situation, one may decide that this option has sufficiently reduced the road mortality of bighorn sheep or not. If the latter is the case, this option may be abandoned in favor of another, or another option may be added to the implementation of an alternative de-icer.

9.3.2 Option 2: Wildlife Fence around Radium Hot Springs and Hwy 93

One may decide that bighorn sheep should no longer have access to the unnatural grasslands on the golf course in Radium Hot Springs, that alternative, more natural grasslands have been provided for on the east side of the road, and that bighorn sheep should not have access to road salt either. If so, one may decide to fence the east side of Hwy 93 until e.g. 5 km south of the Jct in Radium Hot Springs. The fence would then go around the east and south side of Hwy 93, and extend to about 3 km east of the Jct in Radium Hot Springs into Kootenay National Park. In order to avoid relocating collisions with bighorn sheep this project should not be phased but implemented as one. The fence should be accompanied with wildlife jump-outs (e.g. at 300 m interval) for animals that approach the road (and the fence on the east and south side of the road) from the east. This would result in approximately 8 km of wildlife fencing (Can$600,000) and 27 wildlife jump-outs (Can$216,000), at a total estimated cost of Can$616,000.

Should it be unacceptable that animals would still be able to access the grasslands on the golf course and the road salt when coming from the east, wildlife fencing and wildlife jump-outs should also be provided on the west and north side of the road. In addition, wildlife fencing may have to be provided for on the east side or on both sides of Hwy 95, until about 2- km north of the Jct.

This option is likely to result in a substantial reduction in road mortality of bighorn sheep on Mile Hill, unless the herd relocates and will cross the road about 5 km south of Radium Hot Springs to lick road salt there. The herd may also split up in several smaller herds and spread out over the foothills on the west side of the road to forage on (semi-) natural grasslands there.

9.3.3 Option 3: Wildlife Fence and Wildlife Underpass

The fence end would start just south of the village of Radium Hot Springs (point 0.6 km) and end at Radium Hill Road (point 3.4 km). The fence would be installed on both sides of the road (2 * 2.8 km = Can$420,000) and would be combined with wildlife jump-outs (e.g. once every 300 m) (2 8 9 Jump-outs = Can$144,000). The fence on the west side of the road would be positioned lower on the slope at the turn-outs on Mile Hill in order to not obstruct the view of the valley for visitors. In addition, a large mammal underpass would be constructed at about point 1.9 km (Can$250,000). In order to avoid relocating collisions with bighorn sheep this project should not be phased but implemented as one. The total estimated cost for this option are Can$814,000.

In addition to the large mammal underpass, one may consider crossing opportunities for small-medium mammals (e.g. box culverts and pipes under the road) at regular distances (see section 8.5).

One may consider construction of a road run off drainage system to reduce the likelihood that the bighorn sheep will access the road salt in Radium Hot Springs, which may result in an increase of wildlife-human conflicts.

9.3.4 Option 4: Wildlife Fence and Wildlife Overpass

The fence end would start just south of the village of Radium Hot Springs (point 0.6 km) and end at Radium Hill Road (point 3.4 km). The fence would be installed on both sides of the road (2 * 2.8 km = Can$420,000) and would be combined with wildlife jump-outs (e.g. once every 300 m) (2 8 9 Jump-outs = Can$144,000). The fence on the west side of the road would be positioned lower on the slope at the turn-outs on Mile Hill in order to not obstruct the view of the valley for visitors. In addition, a wildlife overpass would be constructed at about point 1.8 km (Can$2,000,000). In order to avoid relocating collisions with bighorn sheep this project should not be phased but implemented as one. The total estimated cost for this option are Can$2,564,000.

In addition to the large mammal underpass, one may consider crossing opportunities for small-medium mammals (e.g. box culverts and pipes under the road) at regular distances (see section 8.5).

One may consider construction of a road run off drainage system to reduce the likelihood that the bighorn sheep will access the road salt in Radium Hot Springs, which may result in an increase of wildlife-human conflicts.

10. RECOMMENDED DATA COLLECTION

10.1 Introduction

The wildlife mortality and wildlife observation data collection program along Hwy 93S in Kootenay and Banff National Park, has been extremely important to the project that this report reports on. Such datasets are not always available, and certainly do not tend to cover such long time periods, in this case up to 33 years. These data allowed the researchers to be more specific than usual with regard to road sections that may require mitigation measures, and where safe wildlife crossing opportunities should be provided for, and for which species they should be designed. The long time period also allowed for some insights into the dynamics of the ecosystem and what may occur within the life span of the proposed mitigation measures.

This chapter provides recommendations for the future data collection with regard to human safety and habitat connectivity for wildlife prior to the implementation of mitigation measures.

10.2 Human Safety

Carcass and collision data relate to human safety and help identify road sections that may require mitigation measures, help prioritize road sections that may require mitigation measures, and allow for monitoring the number of wildlife-vehicle collisions over time. When data collection continues after mitigation measures have been implemented, carcass and collision data also allow for the evaluation of the effectiveness of these mitigation measures. The following issues are important when considering future data collection:

- Consistent search and reporting effort: Consistent search and reporting effort for all road sections and between years is critical for comparisons in time and space.
- Relative measure population size: A relative measure for the population size of the species that are most frequently involved with wildlife-vehicle collisions helps to correct carcass and accident data for potential changes in the population size of the species concerned. Examples of measures of the population size of a species are counts of individuals or pellet groups along transects, or using baited or scented stations where hair samples (DNA) are collected or where photos of the animals are taken.
- Severity of wildlife-vehicle collisions: Recording the severity of wildlife vehicle collisions, including property damage, and potential human injuries and fatalities.

10.3 Habitat Connectivity

The effect of wildlife fencing and safe crossing opportunities on habitat connectivity is relatively difficult to measure. However, a couple of techniques are described below.

- Hardy et al. (2007) developed and implemented a protocol to compare the number of deer and black bear road crossings before a road was reconstructed and wildlife mitigation measures were put in place with the number of deer and black bear movements through wildlife crossing structures that had continuous wildlife fencing in between. Sand tracking beds (100 m long each) were placed along side the road at random locations with road sections that were scheduled to have a concentration of wildlife crossing structures with wildlife fencing in between. Once the wildlife fencing and wildlife crossing structures have been put in place, the animals have, at least theoretically, nowhere else to cross but through the wildlife crossing structures. Therefore the use of the wildlife crossing structures is scheduled to be monitored (sand tracking beds, cameras). To allow for a valid comparison between the exposed tracking beds (before mitigation measures were implemented) and the protected tracking beds (inside the crossing structures), sand tracking beds will also be provided for outside the wildlife crossing structures (Hardy et al. 2007). The sand tracking beds are checked for animal tracks once every 3-4 days. This technique needs to be combined with a relative measure of the population size (see also section 9.2). Measuring wildlife use of safe crossing opportunities also helps increase the understanding of species specific needs for the number, location, type, and dimensions of wildlife crossing structures.

- The authors of this report suggest conducting snow tracking for selected species to measure how long they may travel parallel to a wildlife fence before they either encounter a safe crossing opportunity or give up. It would be ideal if one would be able to distinguish between individuals that have their home range close to the road and dispersers, but that may not be possible. Nonetheless, such tracking data may help understand what the maximum distance between safe crossing opportunities should be.
- The wildlife observations (alive) database managed by Parks Canada may be biased in search and reporting effort towards the south end. The more consistent monitoring of wildlife observations on and close to the road in the Kootenay Valley and along Sinclair Creek and Canyon, eliminates this bias. Given enough time this data base may be preferable to the other data when deciding where to provide safe crossing opportunities for what species in these road sections.
- Wildlife movements can be monitored by equipping multiple individuals of a selected species with a radio collar. Currently GPS radio collars that collect data with a certain time interval are typically preferred over traditional radio collars that have relatively poor positional accuracy and that require relatively great effort to obtain a location. The data collected using radio collars can be used to compare the location and shape of the home ranges of individuals before and after the implementation of wildlife fencing and wildlife crossing structures. These comparisons can show whether an individual was able to maintain its home range on both sides of the road, whether it changed how frequently it crosses the road, and whether the (limited) crossing opportunities may have caused the individual to change the shape of its home range.
- If sufficient data are available and based on a series of assumptions and estimates, wildlife movements can be simulated using a GIS. For the species investigated, modeling wildlife movements can show where animals may be most likely to cross a road and where wildlife crossing opportunities should be located. When combined with population viability models, different configurations of mitigation measures can be investigated and compared with regard to wildlife movements and population viability parameters.

11. FUNDING MECHANISMS AND POTENTIAL PARTNERSHIPS

11.1 Introduction

Sources for funding of wildlife-highway mitigation include a mix of traditional transportation programs, agencies, and interested non-transportation partners. Reducing wildlife-vehicle collisions and enhancing ecological connectivity can have benefits beyond those provided for motorist safety (e.g., reduced wildlife mortality, protection of threatened or endangered species, improved habitat connectivity, reduced maintenance costs for carcass removal, reduced costs for motor vehicle collision insurance). Such benefits reach well beyond the realm of transportation safety, providing the opportunity to develop new sources of funding with non-transportation partners.

To access the greatest amount and variety of funding opportunities requires a partnership of federal, provincial, municipal and non-profit organizations. This is a result of grant programs as well as corporate and private philanthropy that often have restrictions on the type of recipients they can fund. Thus a mix of federal/provincial agencies, municipalities and non-profit organizations maximizes the programs and sources of potential funding to implement and monitor wildlife-vehicle mitigation in the project area. Following are list of potential funding sources or examples of funding sources for the major funding categories if a multi-stakeholder partnership is developed for implementation, monitoring, research and outreach activities.

11.2 National Transportation Funding Sources

In Parks Canada ‘s 2005-2006 Performance Report, one of its six major program activities is to manage throughways so highways are open to through traffic, *are safe and minimize environmental impacts* (our emphasis). This program includes the operation, maintenance and repair of roads, as well as the provincial highways that connect communities and pass through national parks. The Report noted that “between 2005-2006 and 2009-2010, $33.8 million … will be allocated to highway recapitalization for western Canada”. Parks Canada has the opportunity to include Highways 93 and 95 into their highway recapitalization program for western Canada so that wildlife is protected and safety for motorists is enhanced, if not by 2010, for these monies may have already been allocated, then for future fiscal years.

Transport Canada has established the Moving On Sustainable Transportation (MOST) Program to support projects that produce education, awareness and analytical tools to support sustainable transportation. The MOST Program provides funding for projects that stimulate the development of innovative tools, approaches and practices for increasing the sustainability of Canada’s transportation system and realize quantifiable environmental and sustainable development results on Transport Canada’s sustainable development priorities. (www.tc.gc.ca/programs/environment/most/menu.htm).

If the Kootenay Highway project requires the deployment of animal detection systems in high wildlife-vehicle collision road sections, potential funding may be available under the Transport Canada’s Intelligent Transportation Systems (ITS) Initiative, which includes applications such as advanced systems for vehicle safety. Federal funding is provided under the Strategic Highway

Infrastructure Program. Eligible recipients are provinces/territories, municipalities, First Nations, private enterprises, academia, public or private transportation authorities/agencies and not-for-profit organizations. Federal funding will be capped at a maximum of 50% of total eligible project costs. The maximum contribution amount for provinces/territories will be $250,000 per approved project, for the next solicitation of proposals which have not been announced yet (www.tc.gc.ca/ship/absu/its.htm#050, accessed 28 February 2008). ITS research and development includes such areas as safety and the environment.

The Transportation Association of Canada (TAC) is a national association that promotes the provision of safe, secure, efficient, effective and environmentally and financially sustainable transportation services. TAC has a foundation that provides scholarships and fellowships to individuals attending universities, colleges and trade schools for the design of transportation infrastructure, environmental monitoring and mitigation. The foundation also provides funding for transportation research and development at Canadian educational institutions (www.tac-atc.ca/english/educationandtraining/scholarships.cfm).

It may be possible to leverage research and development funding for the Kootenay Highway project with partners across the border in the United States. The US Department of Transportation's Pooled Fund (TPF) Program allows State departments of transportation and the Federal Highway Administration (FHWA) to create synergy by joining forces on planning and research projects of mutual interest. Past pooled funded studies have included provincial agencies and Transport Canada (www.tfhrc.gov/site/04105/index.htm).

11.3 National Non-Transportation Programs and Funding Sources

The Parks Canada Agency has a mandate to protect the ecological integrity (EI) of each of its parks, "Ecological integrity means, with respect to a Park, a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes" (Parks Canada Act, 2001). This, in part, has been the source of funding for the monitoring and research of Banff's 24 wildlife crossings on the Trans-Canada Highway and is a potential source for implementation and monitoring for the Kootenay Highway project.

As a result the EI Program, the federal government allocates funding in the following three areas:

1. **System-Wide Priorities;** to enhance national policy, guidance, science management and monitoring capacity.

2. **Priority Themes;** to provide funding over a 4 year period to a selected number of parks (10) to tackle specific issues under priority themes. Unfortunately, Kootenay National Park is not one of the ten parks selected.

3. **EI Innovation Fund;** to provide resources to Field Units for specific result-oriented projects. Field Units are required to submit EI proposals every year to access this fund and funding can be extended for multiple years for a project.

As of February 2008, Parks Canada's CEO has temporarily suspended the EI program based on an audit of its effectiveness. There is the potential for the agency to reinstate the EI program unchanged or to modify it for future implementation.

The federal government established the Habitat Stewardship Program (HSP) for Species at Risk. The HSP allocates up to $10 million per year to projects that conserve and protect species at risk and their habitats. The HSP seeks to assist the recovery of endangered, threatened, and other species at risk, and to prevent other species from becoming a conservation concern. The HSP provides funding for citizens to implement activities that protect or conserve habitats for species at risk and fosters partnerships among agencies and organizations. More information on the program can be obtained at: www.cws-scf.ec.gc.ca/hsp-pih/default.asp?lang=En&n=59BF488F-1

Environment Canada's Interdepartmental Recovery Fund (IRF) "supports projects submitted by federal departments and departmental corporations for the purpose of implementing priority recovery activities identified in recovery strategies or action plans for extirpated, endangered or threatened species". The Parks Canada Agency has signed the Memorandum of Understanding as a participating agency. This funding can be applied to projects that protect the HSP's species at risk. Application information is at: www.speciesatrisk.gc.ca/support/irf_fir/app_process_e.cfm

The Endangered Species Recovery Fund (ESRF) is a joint effort between the World Wildlife Fund (Canada) and Environment Canada to support recovery activities for species at risk of extinction. The funding is directed to university research and conservation groups. Application information is at: http://www.sararegistry.gc.ca/involved/funding/esrf_e.cfm.

Environment Canada's Ecoaction Program "provides financial support to community groups for projects that have measurable, positive impacts on the environment. EcoAction encourages projects that protect, rehabilitate or enhance the natural environment, and build the capacity of communities to sustain these activities into the future" (www.ec.gc.ca/ecoaction/what_is_e.html). The funding in this program is available for non-profit organizations.

11.4 Provincial and Local Funding Sources

The Insurance Corporation of British Columbia (ICBC) conducts research in cooperation with independent researchers, universities and government agencies. The Corporation's research includes areas such as employing new technologies and improving driver safety. Partnering with ICBC on Highway 93S or 93/95 to increase motorist safety may be of interest to the organization.

The BC Conservation Foundation (BCCF) in partnership with the ICBC formed the Wildlife Collision Prevention Program (WCPP) as a result of the increasing number and severity of wildlife-vehicle collisions in British Columbia. WCPP is administered by the BCCF with funding and support from government agencies, crown corporations, and both public and private organizations. The WCPP researches, evaluates and implements projects that promise to enhance the welfare of the public and wildlife populations. The WCPP may be an excellent partner with Parks Canada for the 93S Project's implementation phase.

The BC Ministry of Environment, Lands and Parks provides funding for wildlife conservation via the Habitat Conservation Trust Fund. The fund "contributes to the conservation and maintenance of the natural productivity and biodiversity of wildlife and habitats in BC". A variety of conservation work is funded via this trust fund. More information to submit a proposal can be found at: www.hctf.ca/app/index.html

The BC Ministry of Environment, Lands and Parks has the Public Conservation Assistance Fund that "provides grants to organizations and individuals who want to provide volunteer labour to complete conservation projects but need financial assistance. Grants are between $2,500 and $10,000." The funding supports individuals to conduct such activities as fencing or tagging animals that accomplish conservation outcomes. For proposal information go to: www.hctf.ca/pubcon/index.html.

The Fish and Wildlife Compensation Fund - Columbia River is a partnership between the BC Ministry of the Environment, BC Hydro and Fisheries and Oceans Canada to conserve fish and wildlife in the Columbia River basin of Canada. Since 1995 they have invested over $50 million in a broad array of projects of which one third has been for species at risk (www.fwcp.ca/). Their website lists many wildlife projects they have funded which vary from bighorn sheep herd augmentation to western screech-owl inventories and breeding status, to northern leopard frog recovery.

Partnering with local communities for the implementation of highway-wildlife mitigation on Highways 93/95 may allow for funding via the Federation of Canadian Municipalities' Green Municipal Fund (GMF). The GMF "provides loans and grants, builds capacity, and shares knowledge to support municipal governments and their partners in developing communities that are more environmentally, socially and economically sustainable". Funding can be allocated to capital projects and studies for transportation or planning. The projects must result in significant environmental improvements or system effectiveness (www.sustainablecommunities.fcm.ca/GMF/).

Another reason for partnering with local communities for the implementation of highway-wildlife mitigation on Highways 93/95 may allow for funding via British Columbia's Ministry of Community Services' Towns for Tomorrow program which "opens the door for B.C.'s smaller communities to improve their local infrastructure and become even better places to live and work". The program provides $21 million for capital investments that enhance and/or protect recreation, tourism or cultural amenities. This fund may allow for mitigation of bighorn sheep on highways and roads outside the Park's boundaries (www.townsfortomorrow.gov.bc.ca/).

11.5 Private Foundation Funding Opportunities

While transportation infrastructure is generally financed through a combination of local, provincial or federal funding, private foundation philanthropy can increase funding efficiency by helping to leverage or match public funds for research, education, and outreach efforts. Most private philanthropy is focused on granting to non-profit organizations organized under Revenue Canada. Thus, for the Kootenay project's wildlife monitoring to receive private funding, it may be incumbent on the Parks Canada Agency to collaborate with non-profit organizations.

A search for grants via the paid research service www.bigdatabase.com using two keywords "British Columbia" and "wildlife" listed 242 private foundation funding sources. This does not guarantee that they would fund the Kootenay Highway project's implementation, monitoring, and outreach. However, it does demonstrate the strong and diverse interest in wildlife conservation by private foundations in British Columbia.

A provincial-focused grantmaker is exemplified by the Endswell Foundation which funds organizations dedicated to conservation and related public education in British Columbia. Program priorities include the preservation of terrestrial biodiversity. However, the Endswell Foundation can only make grants to organizations registered as charities with Revenue Canada. (www.endswell.org). Therefore, partnerships with non-profits for the Kootenay Highway project would allow pursuit of funding from this grantmaker and many others with similar interests.

Another example of a provincial-focused private foundation is the Vancouver Foundation with funding interests in the environment, education and animal welfare. "Through partnerships with donors and agencies, Vancouver Foundation supports hundreds of much-needed and innovative projects in communities throughout British Columbia". (www.vancouverfoundation.bc.ca/grants/index.htm).

Similarly, the growth, healthy economy and impact of Calgary and other Alberta communities recreating in the mountain parks or passing through to the Columbia Valley via Highway 93S may create philanthropic interest by individuals and foundations in Alberta for the Kootenay Highway project. Some foundations that support wildlife conservation, such as the Calgary Foundation and the Alberta Ecotrust limit their giving to projects in Alberta, while other Calgary-based foundations, such as the Carthy Foundation (www.carthyfoundation.org) or the Max Bell Foundation (www.maxbell.org) have a broader geographic scope, including British Columbia.

Nationally there are many private foundations that have interests across Canada, such as the McLean Foundation in Toronto (www.mcleanfoundation.ca) or the ELJB Foundation based in Montreal (no website available). These are but two examples of private foundations that support a diverse array of wildlife conservation efforts across Canada.

Internationally, there are many private foundations in the United States that support conservation of wildlife in Canada. Some may be within the context of transboundary cooperation under such umbrellas as the Yellowstone to Yukon Conservation Initiative (see the Wilburforce Foundation at www.wilburforce.org), others may simply have organizational interest in international conservation (i.e, the Weeden Foundation of New York, www.weedenfdn.org).

11.6 Corporate Philanthropy

Hundreds of Canada's corporations have a long history of philanthropy, and many have established their own foundations to facilitate their giving. In addition, some have programs that match employee contributions, provide in-kind gifts or provide volunteers for projects. This project's wildlife crossings, other mitigation efforts, focus on maintaining habitat connectivity and research efforts may be eligible to receive support from such corporate conservation, environmental, or community programs.

A free on-line search for corporate funding sources is available at Fundsnet Services Online (www.fundsnetservices.com/) and lists both corporate and private foundation programs in Canada with links to their websites. One such example is the link to the Allstate Foundation of Canada (www.allstate.ca/En/In+Our+Community/). The Foundation “was established in 1977 to provide grants to charities and not-for-profit organizations that are involved in a variety of activities or educational initiatives around crime prevention, road safety and home safety”. Thus, the Kootenay Highway project’s focus on improving highway safety by reducing wildlife-vehicle collisions may be of interest to Allstate. However, granting is to non-profit organizations only.

An example of a corporate foundation that disperses its funding nationally would be the TD Friends of the Environment Foundation that supports environmental causes across the country. “Since 1990, TD Friends of the Environment Foundation has contributed over $42 million in support of more than 16,000 environmental projects in communities across Canada”. Their information indicates TD Friends supported projects in national parks and in British Columbia (www.td.com/fef/).

Another example of business philanthropy is by the Mountain Equipment Co-op, founded in 1971, which is a member-owned chain of stores across Canada and is based in Vancouver. It focuses its funding on conservation and outdoor recreation and allows support for research. MEC’s giving is nation-wide. It has an on-line application process (www.mec.ca/Apps/grantApp/mecGrantAppIntro.jsp?FOLDER<>folder_id=2534374302884545&bmUID=1203447695714).

11.7 Creative Potential Funding Sources

Voluntary contributions at Parks Canada entrance stations, such as the one at Radium Hot Springs, directed to reduce highway-wildlife mitigation for Highway 93 may be worthwhile exploring. A tri-fold and mail-in envelope explaining the need and the use of the contributions could be included with the information packets given to park visitors at the West gate. A “Safe Passages Fund” for motorists and wildlife, set up by Kootenay National Park, may be worthwhile exploring with Park managers. Alternatively, if this is not possible to be used at Park entrance stations, then community businesses and Park vendors may need to be recruited to distribute the tri-fold and envelopes to motorists.

In the United States, many national parks have non-profit organizations whose mission is to support efforts in the national parks. The National Park Foundation has helped to fund important conservation, preservation and education efforts. The National Park Foundation grants over $31 million annually in cash, services or in-kind donations to the National Park Service and its partners. Grants range from small "seed" or start-up funding to larger, multi-year projects: http://www.nationalparks.org/AboutUs/AboutUs-ProgramsGrants.shtml. Individual national parks may also enjoy a local foundation developed for their benefit, such as the Yellowstone National Park Foundation and Grand Teton National Park Foundation. Other parks have subsidiaries of the National Park Foundation (for example, the Glacier Fund for Glacier National Park). Exploring local interest in setting up a non-profit to support Kootenay National Park may be a worthy endeavor and would not be limited to wildlife-vehicle collision mitigation.

11.8 Conclusion and Recommendation

There are a wide variety of funding sources that have the potential to support the reduction of wildlife-vehicle collisions and enhance ecological connectivity along Highway 93 South in Kootenay and Banff National Parks and Highways 93/95 near the Radium Hot Springs entrance to Kootenay National Park. A mix of federal, provincial and private wildlife conservation programs exist that could be tapped for implementation, monitoring, research and outreach activities.

To attract the widest variety of funding support it is recommended that:

- Kootenay National Park take the lead to create a working group of partners interested in jointly deploying solutions for highway-wildlife issues on Highways 93 South and 93/95. This group will be most successful if it has representatives from Parks Canada, provincial government agencies, local communities, research/academia and the non-profit sector.
- If a broad group of interested partners are willing to work together, it may be necessary to recruit or assign a coordinator to the project to facilitate joint activities and to organize fundraising efforts.
- The potential for creative new funding sources be explored.

12. CONCLUSIONS

The long term wildlife mortality and wildlife observation data collection program along Hwy 93S in Kootenay and Banff National Park allowed the researchers to be more specific than usual with regard to the identification of road sections that may require mitigation measures, the prioritization of these road sections, where safe wildlife crossing opportunities should be provided for, and for which species they should be designed. The long time period also allowed for some insights into the dynamics of the ecosystem and what may occur within the life span of the proposed mitigation measures. Nonetheless, the identification and prioritization of the road sections that may require mitigation were based on the assumption that search and reporting effort for road killed animals and animals seen alive on or near the road was similar for all road sections.

The research team developed a mitigation plan that identified road mortality clusters and mitigation zones based on 33 years of road mortality data (1975 through 2007). The research team used the most recent ten years of the road mortality data (1998 through 2007) to prioritize road sections within these mitigation zones. Wildlife observation data (1975 through 2007), both from animals found dead and seen alive along the road corridor, were used to identify wildlife observation clusters which provided a basis for the location of safe crossing opportunities. These wildlife observations also allowed the research team to identify the most commonly observed species in these wildlife observation clusters which provided guidance for the type and dimensions of the safe crossing opportunities.

The research team provided a package of tools and data that allows the users of this report to compile alternative configurations of mitigation measures. These tools and data include ranking values for road mortality clusters that allow for the prioritization or selection of the road sections where mitigation measures may be most needed, a breakdown of the species involved with wildlife-vehicle collisions in each mortality cluster, species specific wildlife observation data for the mitigation zones, ranking values for wildlife observation clusters that allow for the prioritization or selection of road sections where safe crossing opportunities may be most needed, a breakdown of the species observed in each wildlife observation cluster, a procedure for the distance between safe crossing opportunities based on the diameter of the home range of the species of interest, and indicative cost estimates for the recommended mitigation measures. These data are presented in the text (primarily as tables) as well as in the appendixes.

The length of the mitigation zones in Kootenay and Banff National Park was 63.3% of the total road length while 79.7% of all reported road mortalities fell within these mitigation zones. The length of the mitigation zones in and around Radium Hot Springs was 37.4% of the total road length while 83.1% of all reported bighorn sheep road mortalities fell within these mitigation zones.

The research team provided cost estimates for the mitigation measures. The proposed mitigation measures in Kootenay and Banff National Park are estimated at Can$20,920,000 (indicative cost estimate, wildlife fencing and crossing opportunities for large mammals only). The proposed mitigation measures in and around Radium Hot Springs are estimated at Can$2,440,000 (indicative cost estimate, wildlife fencing and crossing opportunities for large mammals only). About half of the costs of the mitigation measures were based on wildlife fencing, and the other half were based on safe crossing opportunities for wildlife.

The research team formulated options and potential strategies for alternative configurations of mitigation measures, especially those that may lead to a reduction in cost for the mitigation measures. The main strategies include implementing the mitigation measures on shorter sections, increasing the distance between safe crossing opportunities, and alternative types and smaller dimensions of the safe crossing opportunities. With regard to shorter sections of wildlife fencing, especially in the Kootenay Valley, the research team would like to stress that this may lead to a shift in the location of wildlife-vehicle collisions rather than a reduction in wildlife vehicle collisions. This applies especially to white-tailed deer and elk, species thought to be highly dependent on the grass-herb vegetation in the right-of-way. On the other hand, fencing out the right-of-way along long road sections in the Kootenay Valley may cause white-tailed deer to be displaced, or may cause a strong reduction in their number.

The research team suggested where to start with the mitigation measures; south of Kootenay Crossing in Kootenay National Park, and on Mile Hill just south of Radium Hot Springs. For both locations, the research team described various options, including indicative budgets. The mitigation measures south of Kootenay Crossing can be phased. For option 1, wildlife fencing with animal detection systems, phases typically require Can$230,000 alternated with phases that typically require Can$35,000. For option 2, wildlife fencing with large mammal underpasses, phases typically require Can$232,000 alternated with phases that typically require Can$250,000. The work can be stopped or delayed after each phase until sufficient funds available for the next phase.

Finally, the research team provided recommendations for future data collection and an overview of potential funding mechanisms and partnerships for the implementation of the mitigation measures.

The proposed mitigation measures are likely to reduce wildlife-vehicle collisions on the mitigated road sections by about 87%, at least for large mammal species. In addition; the proposed safe crossing opportunities are expected to result in a highway permeability that is meaningful for the individuals that live in the areas adjacent to the highway. However, the research team would like to emphasize that the proposed mitigation measures do not necessarily guarantee viable populations for the selected species. Road mortality will still occur, especially in the unmitigated road sections, and the level of habitat connectivity provided through the safe crossing opportunities may or may not be sufficient to maintain viable populations on the long term. The research team would like to emphasize that, should there be substantial concerns with regard to the costs for mitigation measures and whether the safe crossing opportunities that would be provided offer sufficient habitat connectivity, there remains the option to not implement the mitigation measures and accept current, and increasing, levels of road mortality and the current, and most likely increasing, barrier effect of highway 93S.

While the costs for the proposed mitigation measures may seem high, the mitigation measures also reduce costs to society by reducing wildlife-vehicle collisions with an estimated 87% in the mitigation zones. For the road sections in Kootenay National Park, the proposed mitigation measures would have to prevent about 53 collisions with large animals per year to break even. The reported number of collisions with large animals in the mitigation zones has been about 50 per year in recent years, and, assuming a reduction of 87%, the mitigation measures may prevent about 44 collisions with large animals per year, relatively close to the break-even point. Similarly, for the road sections in and around Radium Hot Springs, the mitigation measures would have to prevent about 4 collisions with large animals per year to break even. The reported number of collisions with bighorn sheep has been about 10 per year in recent years, and, assuming a reduction of 87%, the mitigation measures may prevent about 9 collisions with bighorn sheep per year, substantially more than the break-even point.

The research team encourages the users of this report to be flexible with the interpretation of the proposed mitigation measures. Due to time constraints and the time of year this project was conducted, detailed field investigations and verifications were not possible (snow cover), and the research team recommends such field investigations and verifications before final decisions are made with regard to the beginning and ending of wildlife fencing and the exact location of safe crossing opportunities. In addition, in areas with long sections of wildlife fencing, one may consider modeling wildlife movements and population viability for different configurations of mitigation measures.

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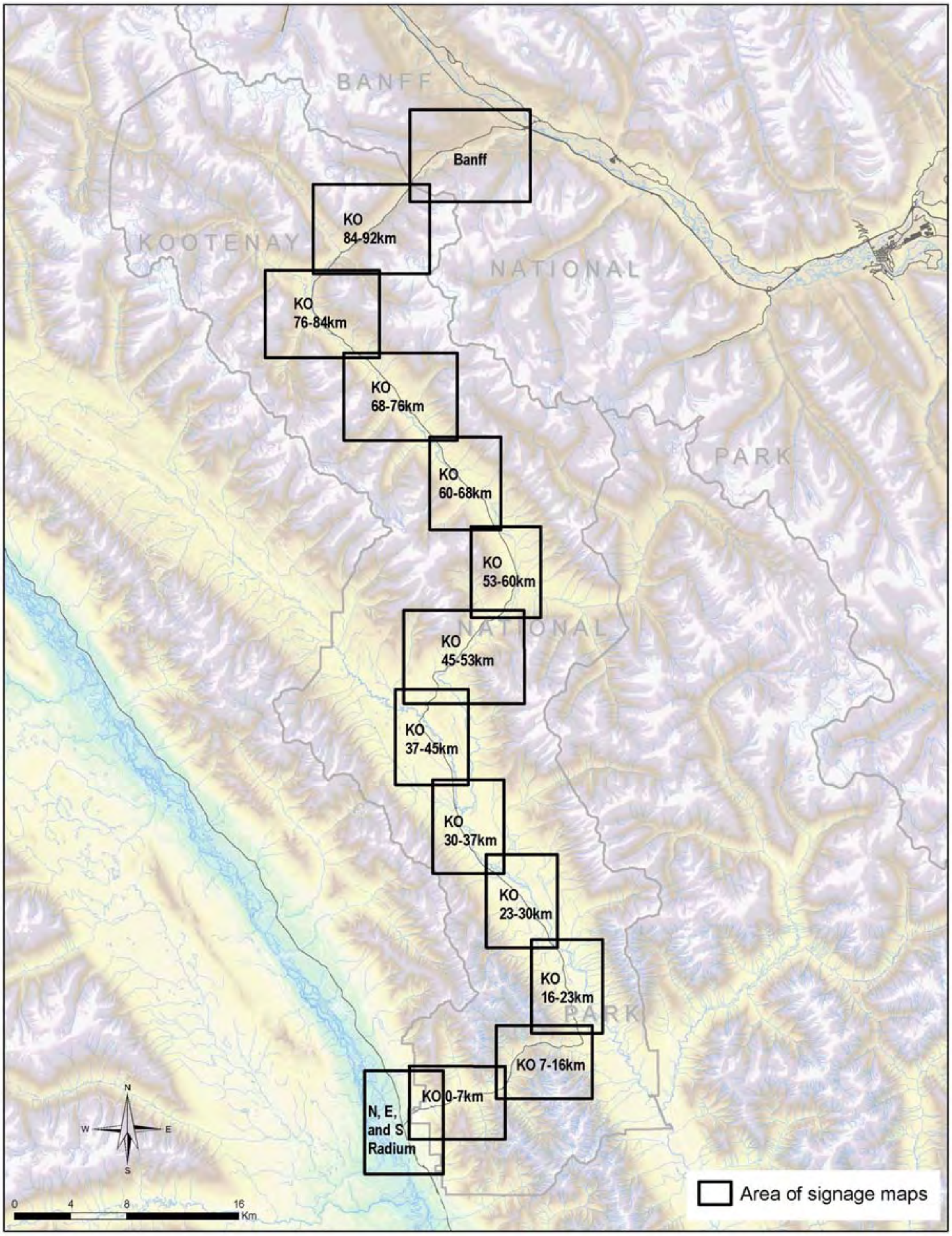
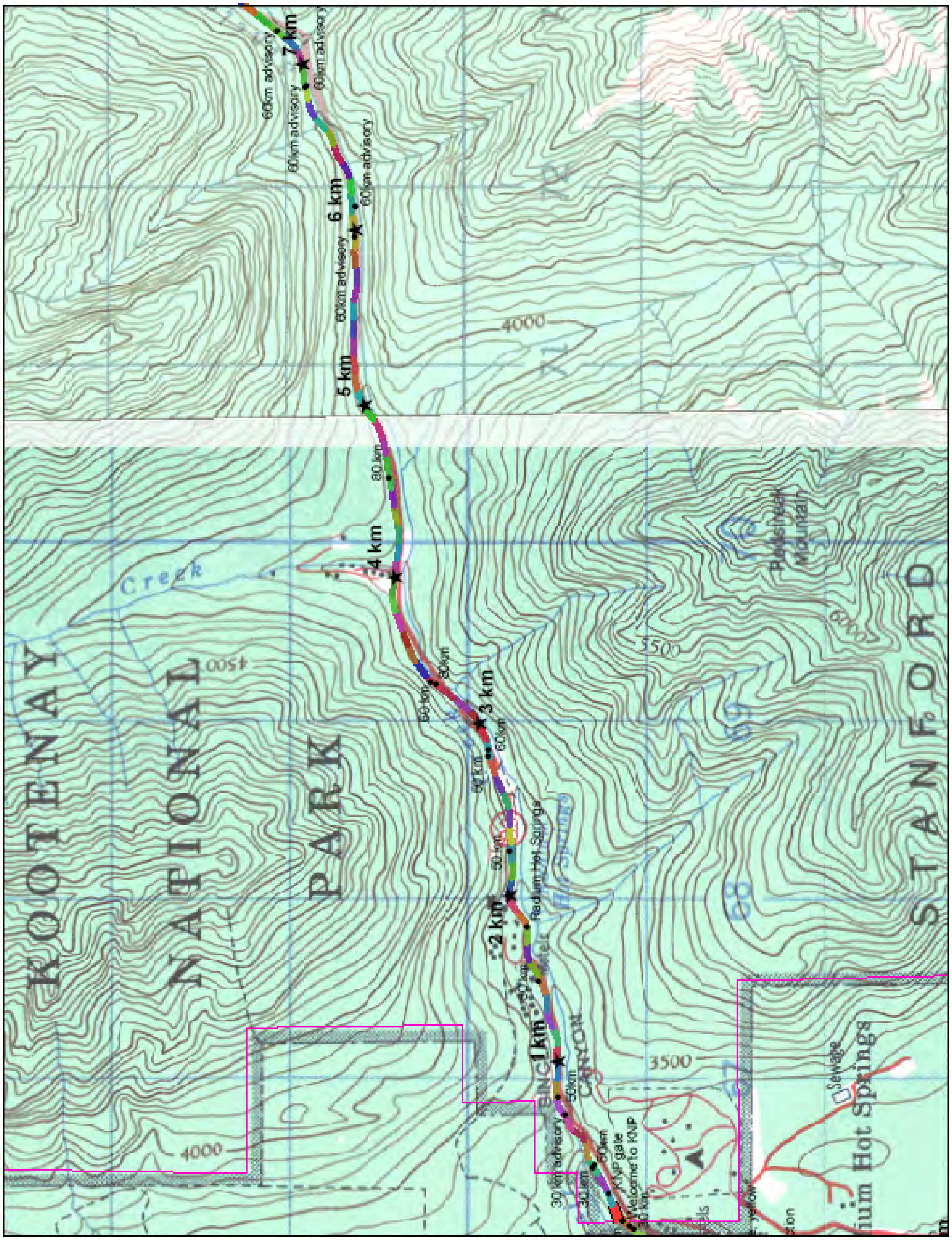
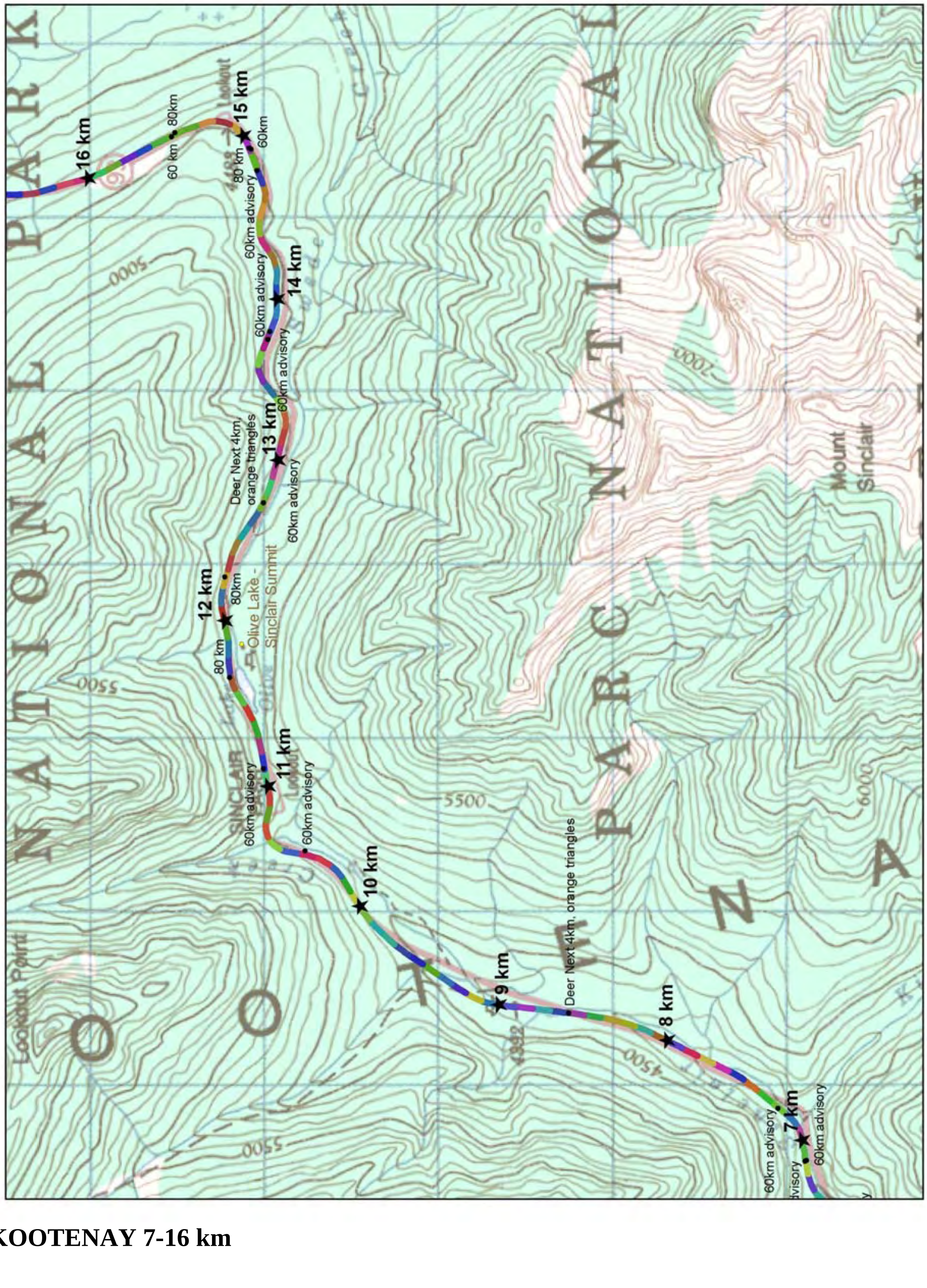
APPENDIX A: TOPOGRAPHIC MAPS WITH 100M ROAD UNITS

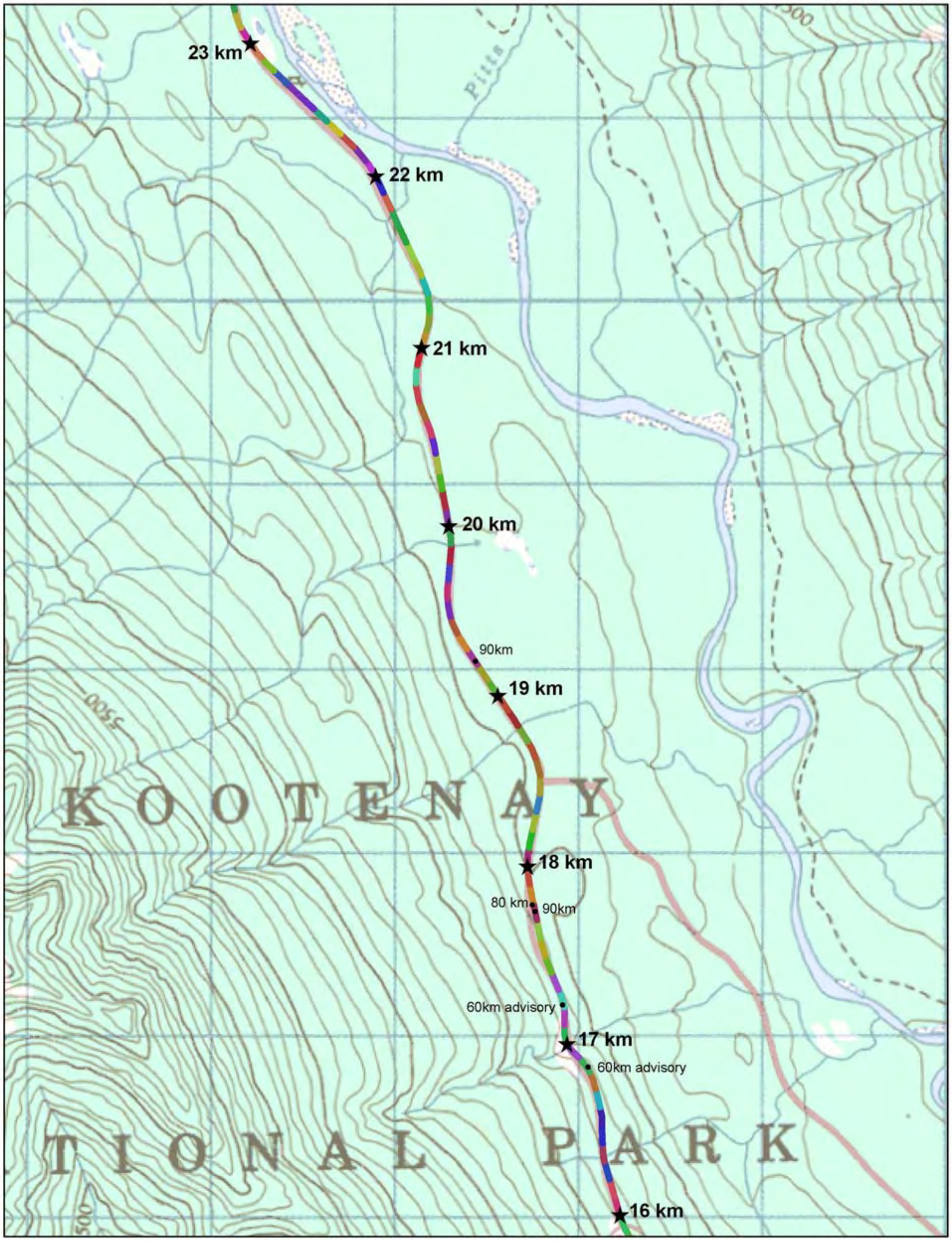




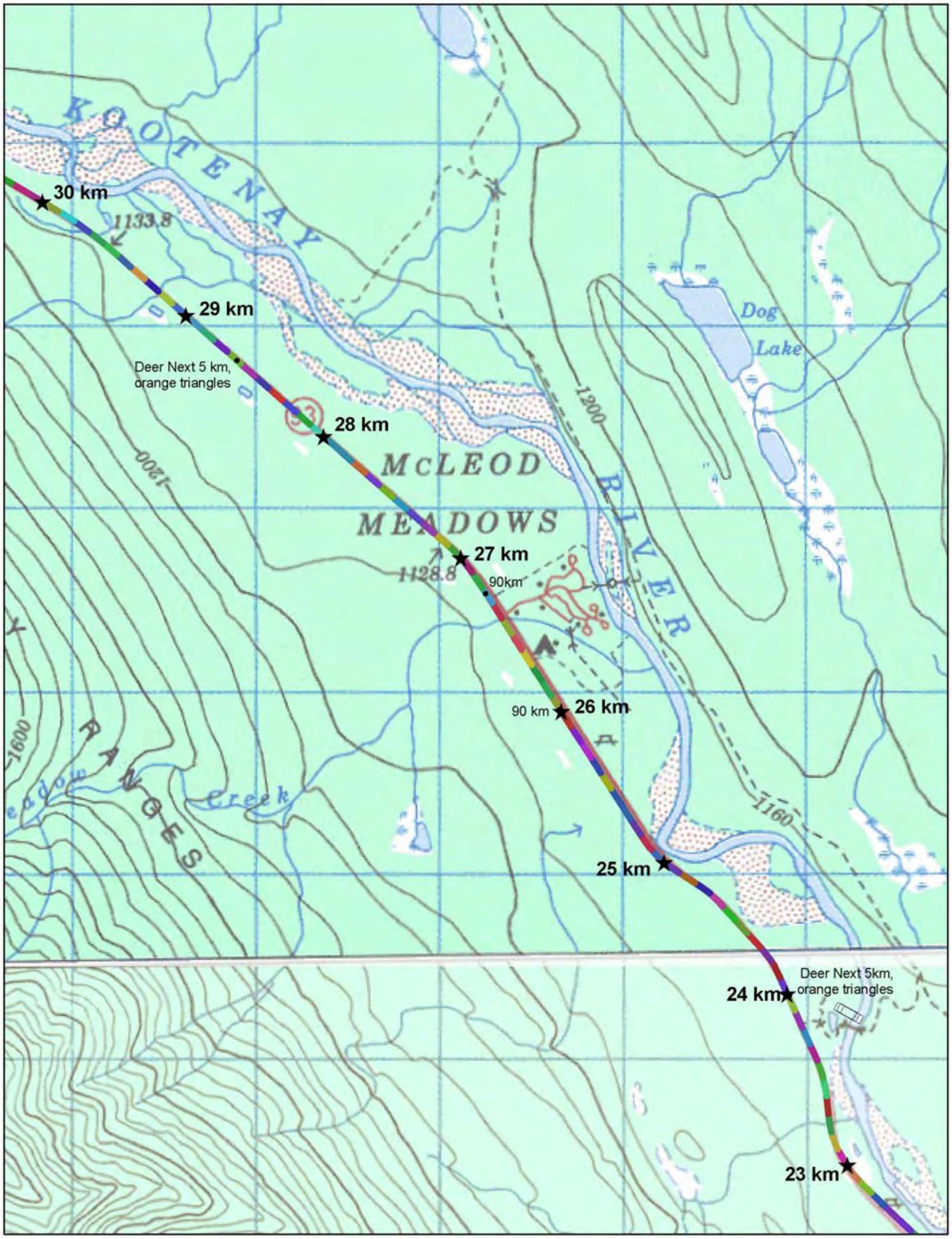
KOOTENAY 0-7 km



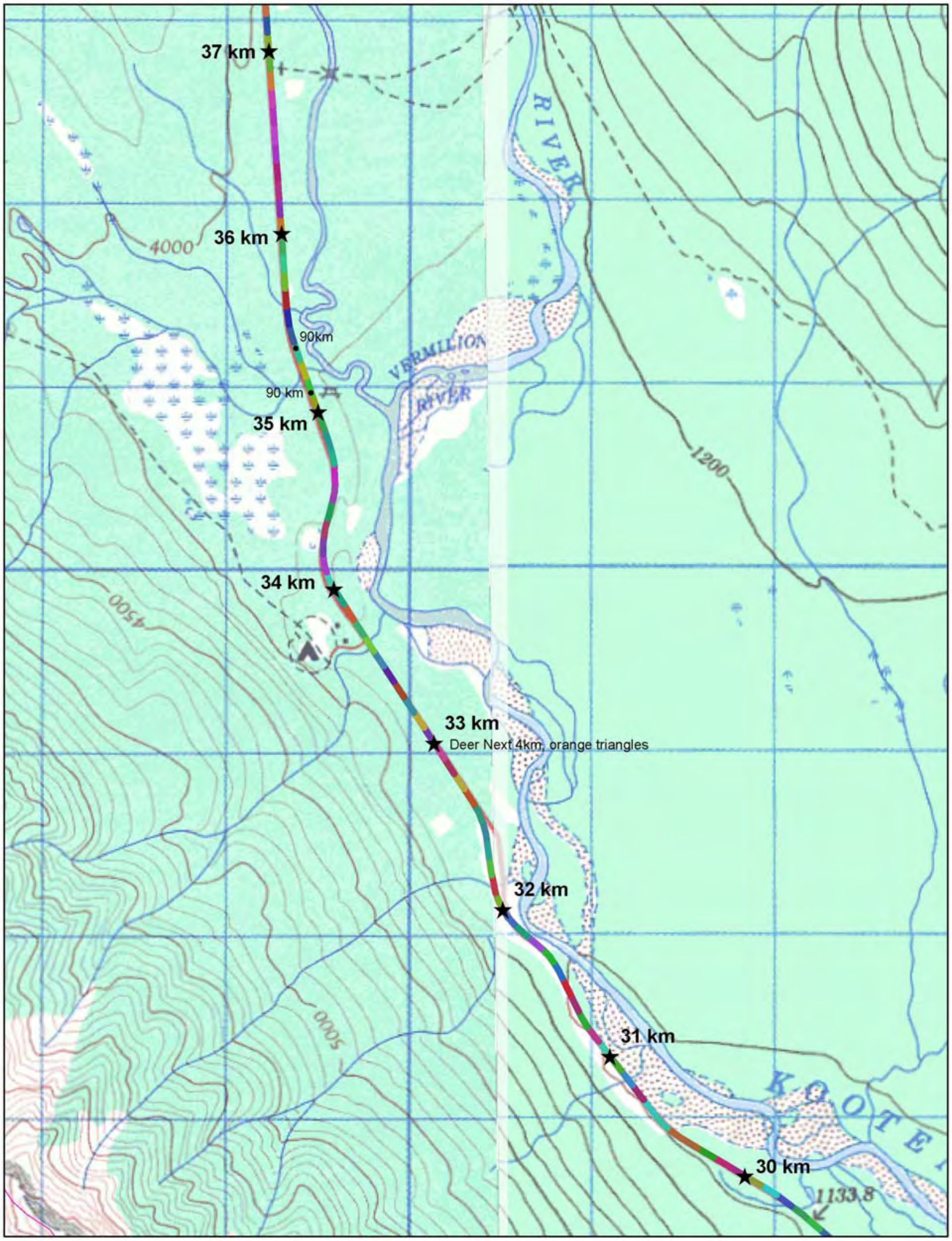
KOOTENAY 7-16 km



KOOTENAY 16-23 km

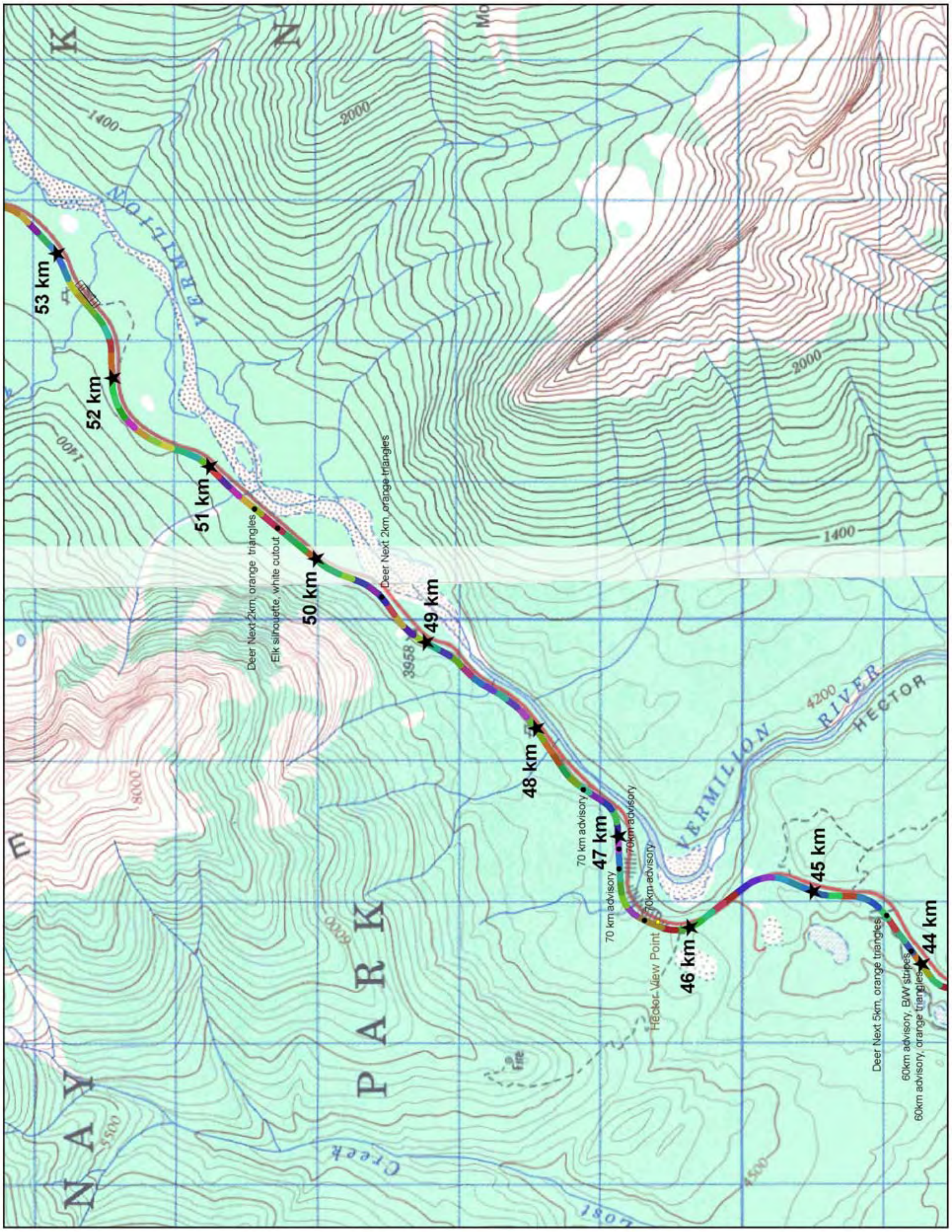


KOOTENAY 23-30 km

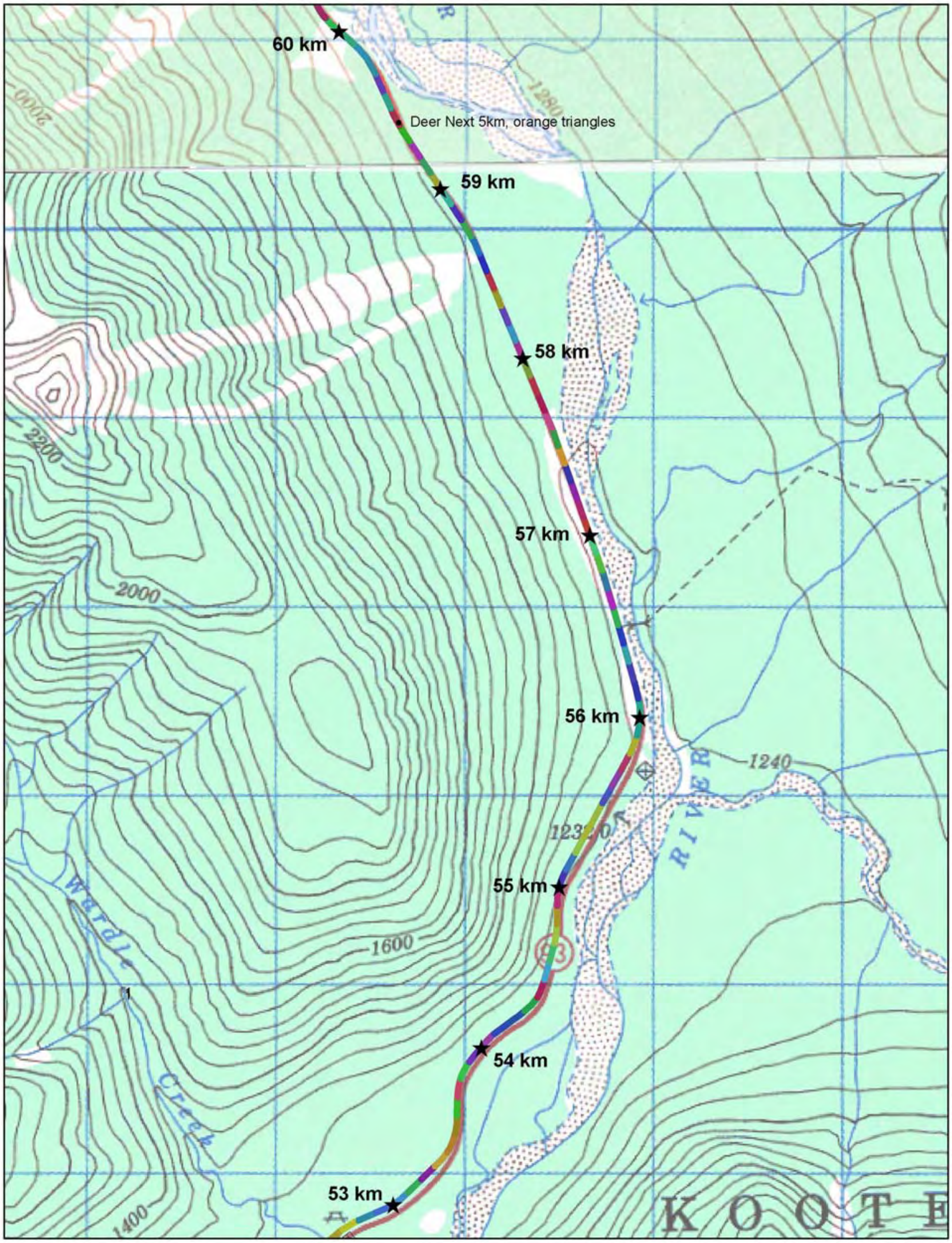


KOOTENAY 30-37 km

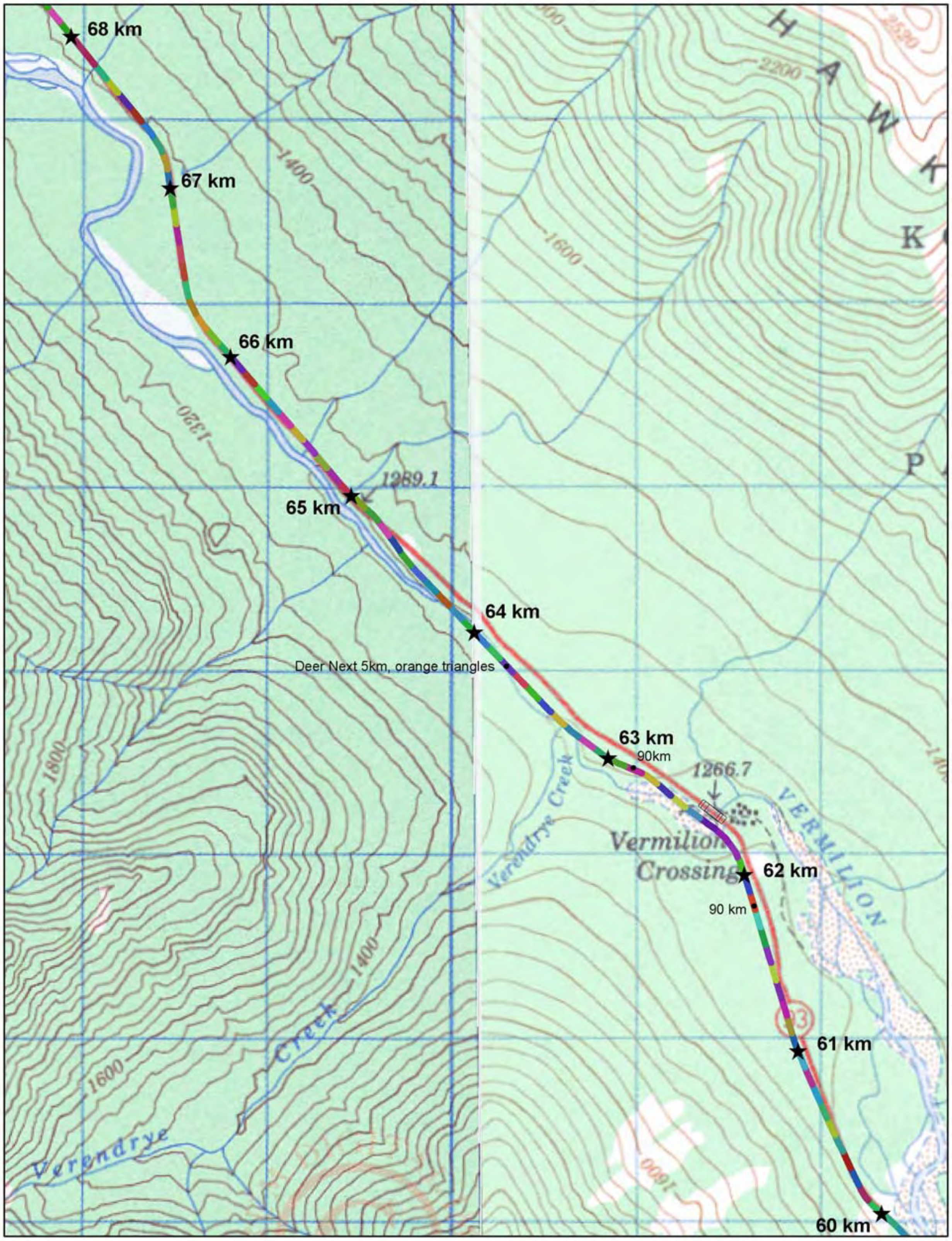
KOOTENAY 37-45 km



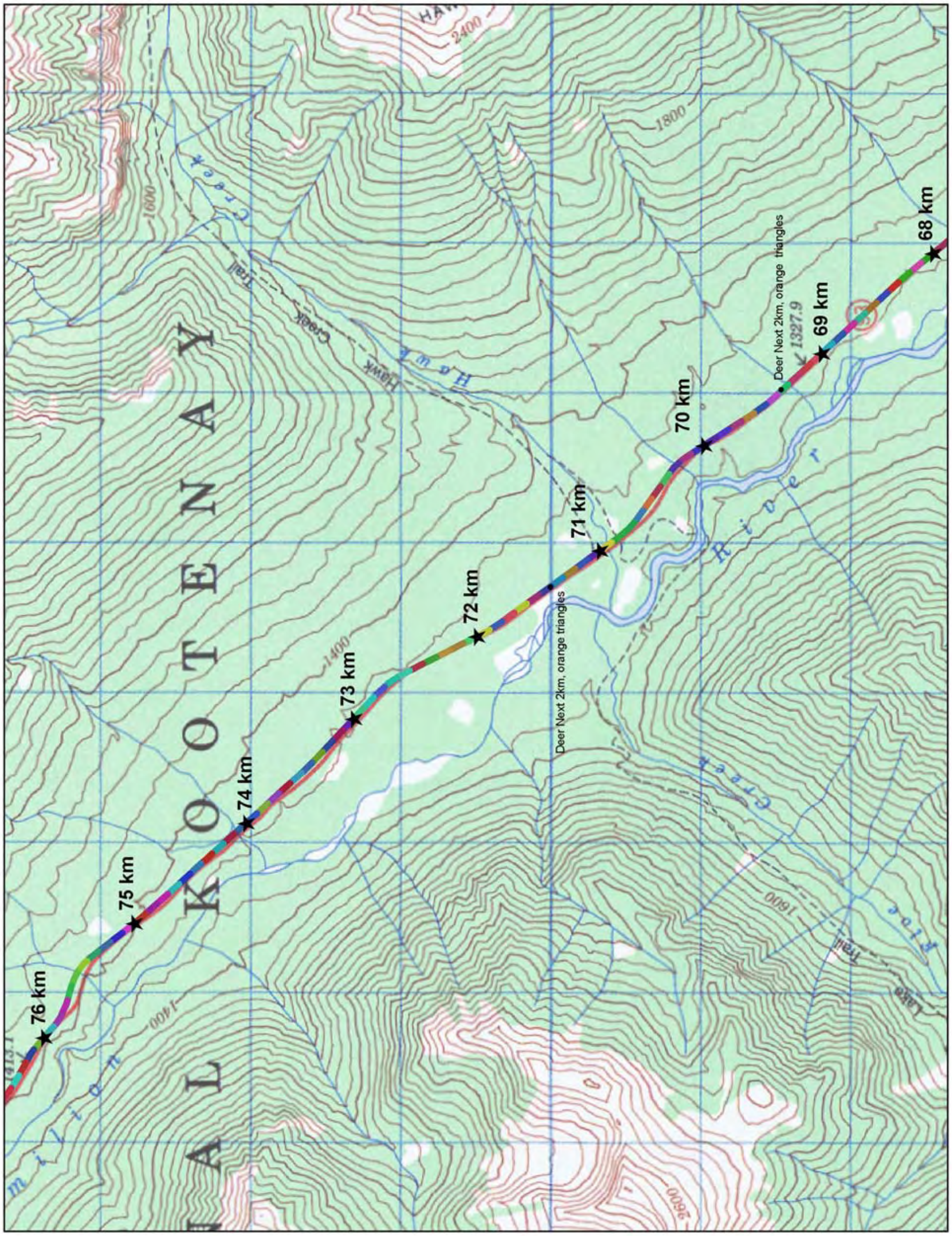
KOOTENAY 44-53 km



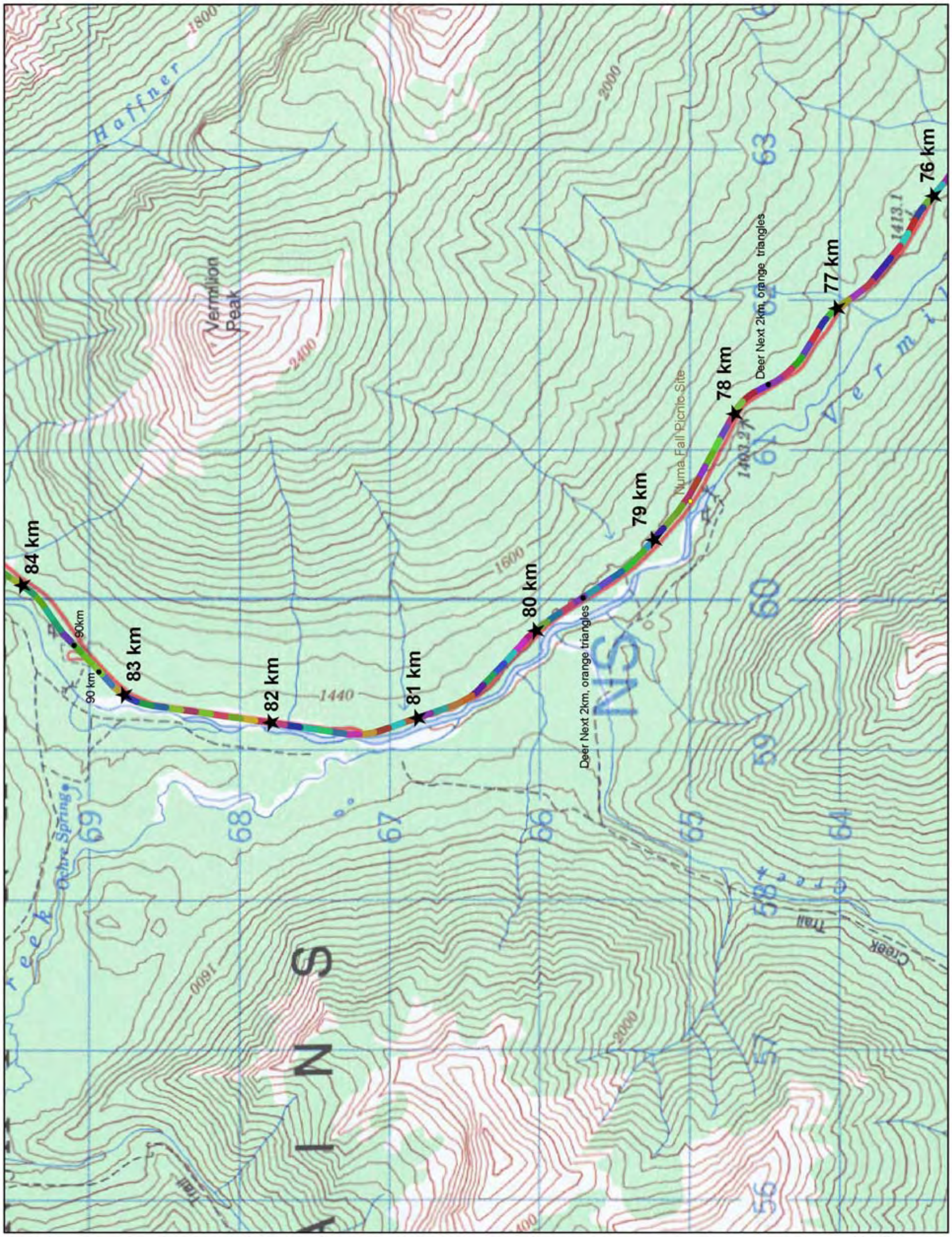
KOOTENAY 53-60 km



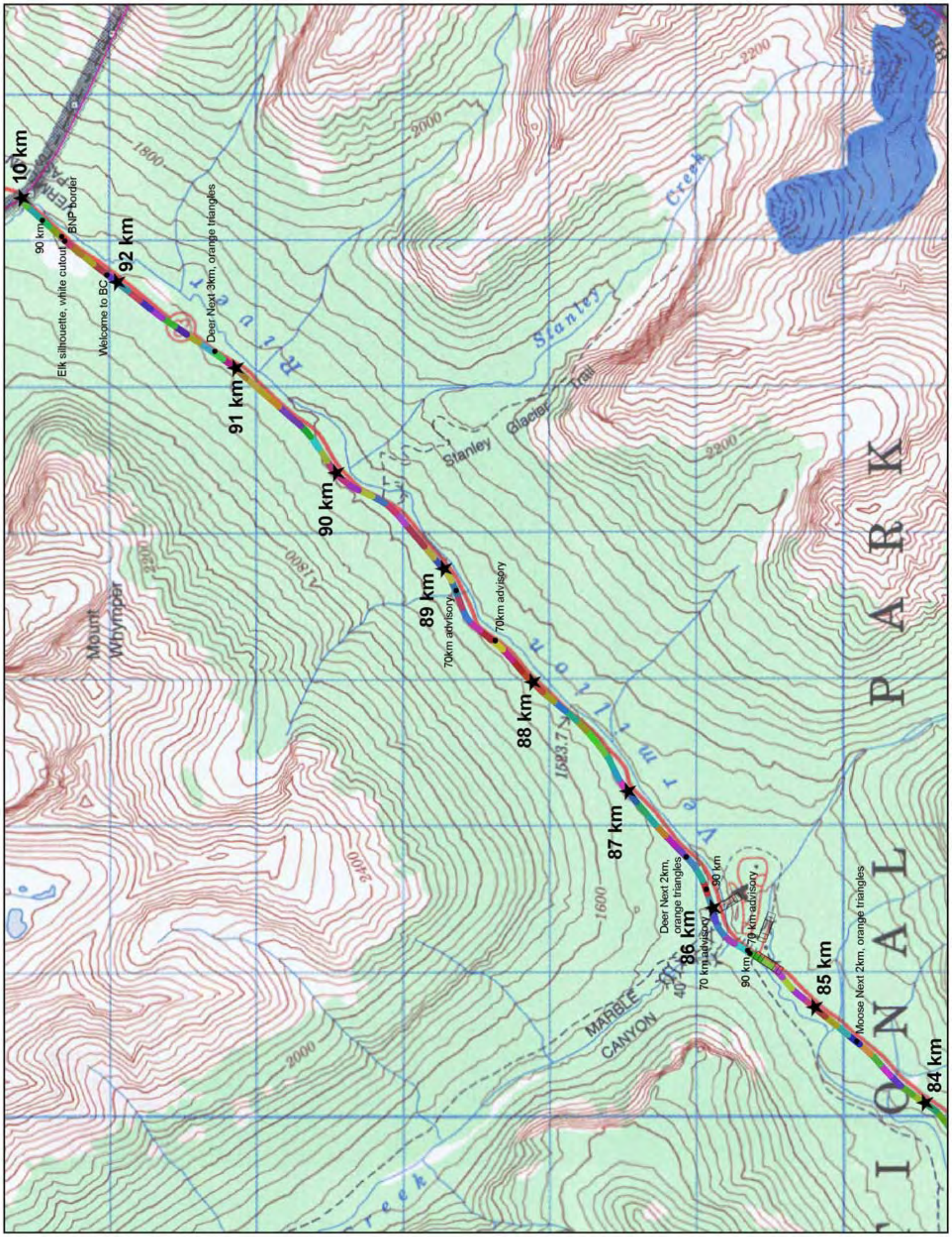
KOOTENAY 60-68 km



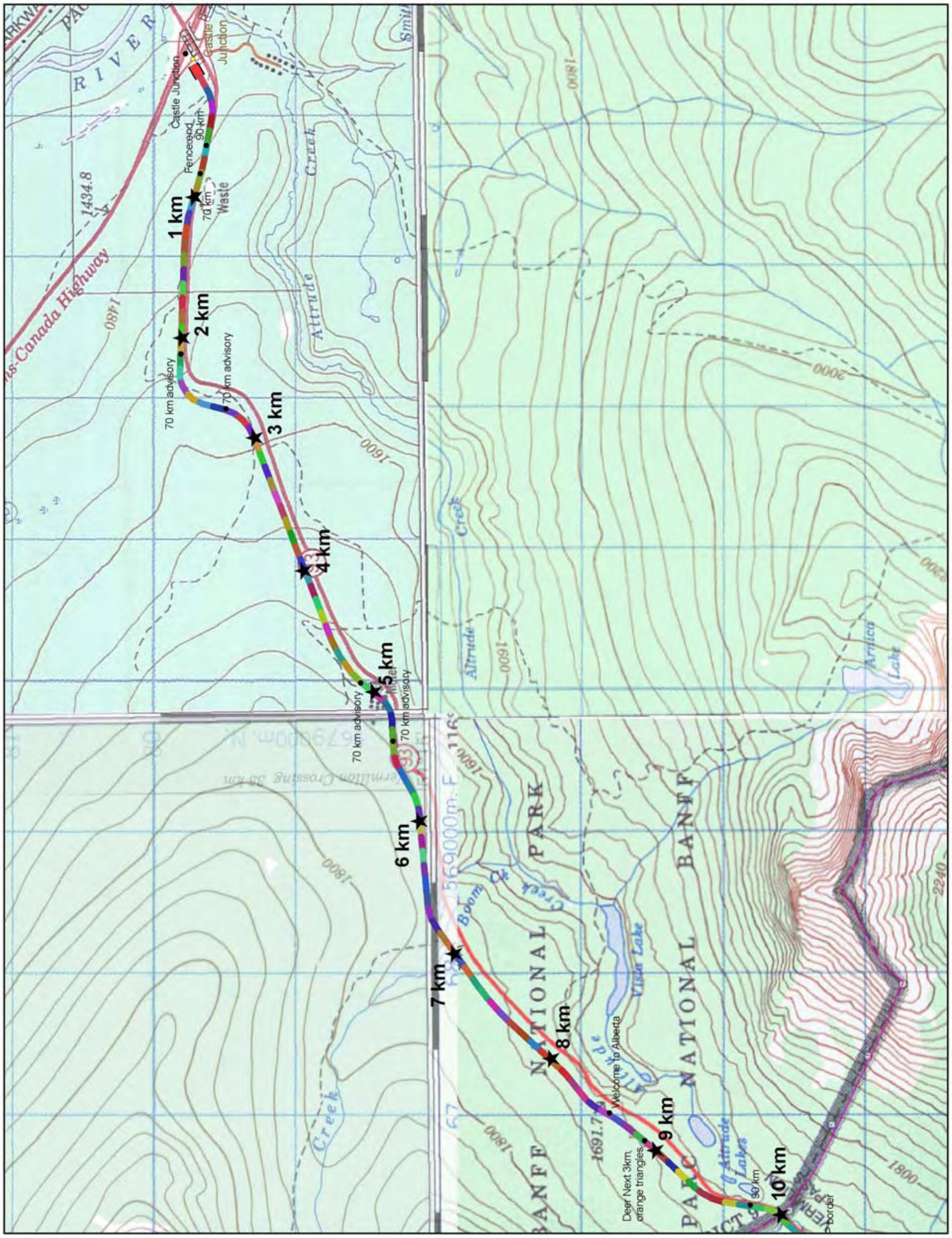
KOOTENAY 68-76 km



KOOTENAY 76-84 km

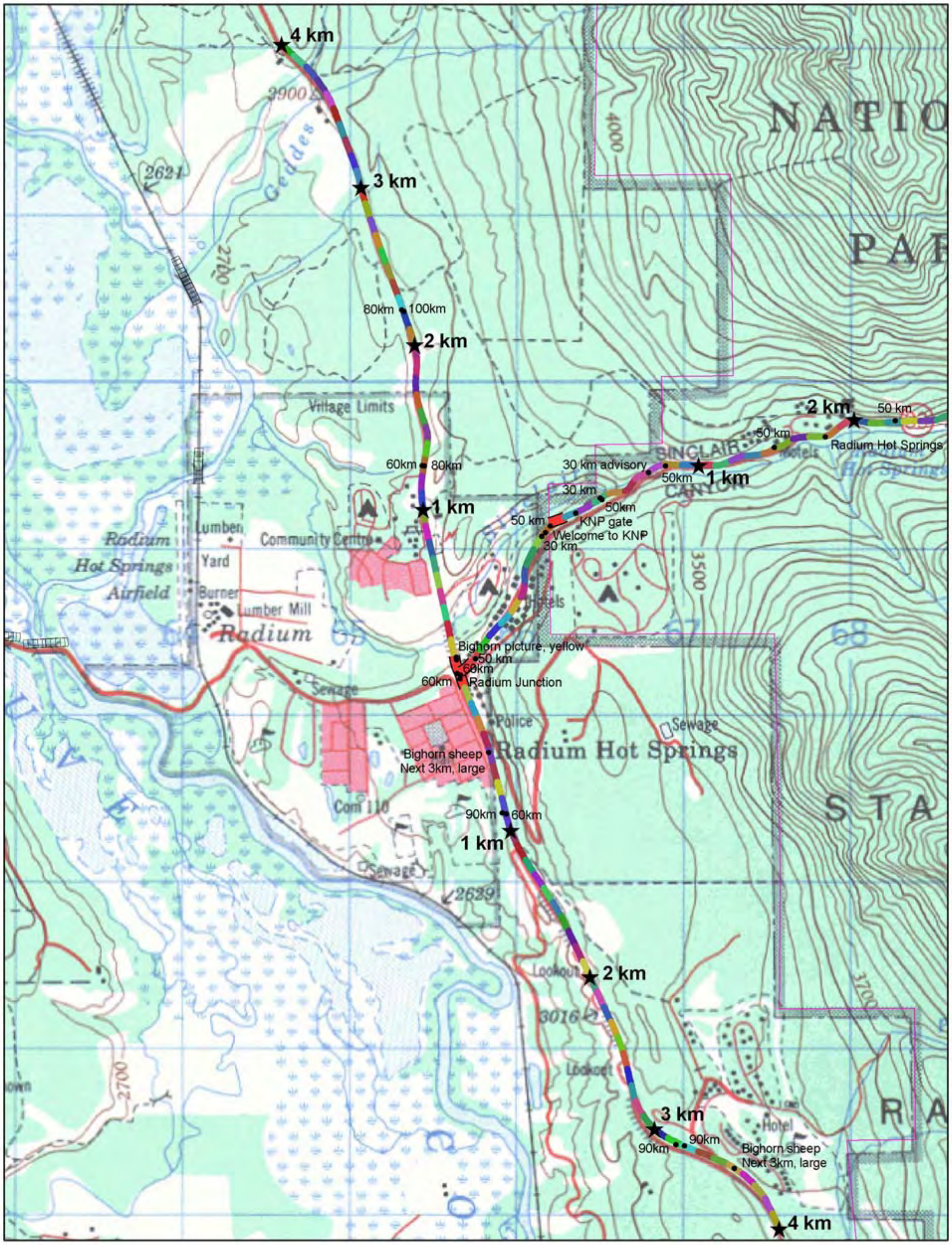


KOOTENAY 84-92 km

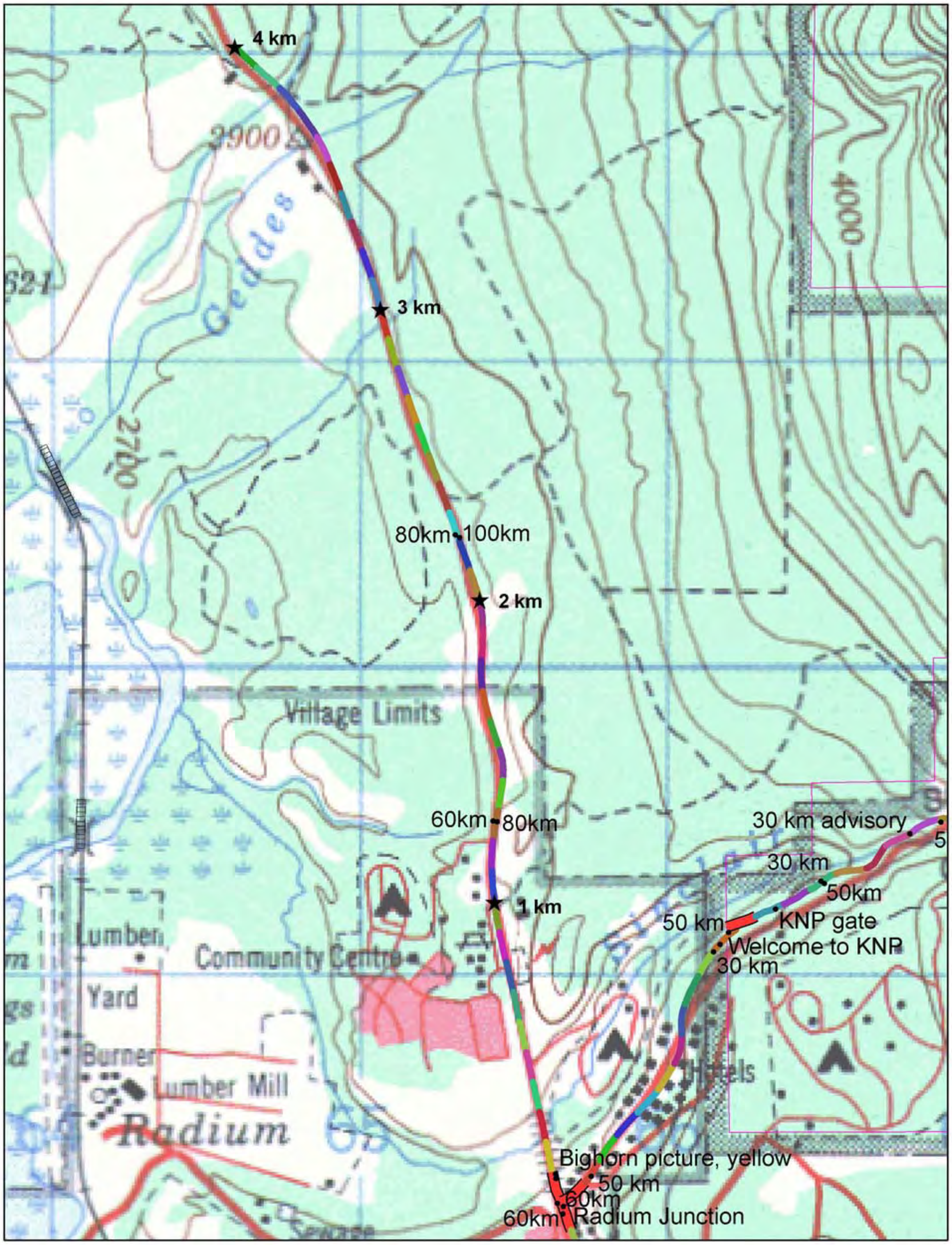


Castle Junction
Fence end
90 km
70 km
Waste
1 km
2 km
70 km advisory
70 km advisory
3 km
4 km
5 km
70 km advisory
70 km advisory
6 km
7 km
8 km
Welcome to Alberta
9 km
Deer Next 3km, orange triangles
90 km
10 km
border
Altrude
Creek
Vista Lake
Arnica Lake
NATIONAL PARK
BANFF NATIONAL
1691.7
1434.8

BANFF 0-10 km



RADIUM HOT SPRINGS (NORTH, EAST AND SOUTH)



RADIUM HOT SPRINGS (NORTH AND EAST)

RADIUM HOT SPRINGS (SOUTH)

APPENDIX B: KOOTENAY CLUSTER CATEGORIES, MITIGATION ZONES AND CLUSTERS

The number of observations per road unit, associated wildlife mortality road value or wildlife observation values, and cluster categories for 33 year road mortality clusters, 10 year road mortality clusters, and wildlife observation clusters within mitigation zones are provided for the Kootenay study area road section. The lined black box in the 33 year road mortality clusters cluster category column displays the mitigation zones. The lined gray box in the Wildlife Observation Clusters in Mitigation Zones depicts proposed locations of safe crossing opportunities.

Shading indicates:

- "33 year road mortality clusters" in the 33 Year Mortality Clusters data columns
- "10 year mortality clusters" in the 10 Year Mortality Clusters data columns
- "Wildlife observation clusters" in the Wildlife Observation Clusters in Mitigation Zones data columns

The locations of shading and boxes display 100 m road units. A 100 m road unit includes observations from the start of the named unit to its last (100) meter. For example, observations occurring between km 16.20 and 16.29 are assigned to the 16.2 road unit, while an observation occurring at 16.30 is assigned to the 16.3 road unit.

	33 Year Mortality Clusters			10 Year Mortality Clusters			Wildlife Observation Clusters in Mitigation Zones				
Road unit	**Mortality observations**	**Wildlife road mortality values**	**Cluster category**	**Mortality observations**	**Wildlife road mortality values**	**Cluster category**	**Incidental observations**	**Mortality observations**	**Total incidental and mortality**	**Wildlife observation values**	**Cluster category**
0.0	2	3	Medium	1	1	Very low, low, medium					
0.1	0	2	Low	0	1	Very low, low, medium					
0.2	0	1	Very Low	0	0	Absent					
0.3	1	1	Very Low	0	0	Absent					
0.4	0	2	Low	0	1	Very low, low, medium					
0.5	1	2	Low	1	1	Very low, low, medium					

0.6	1	3	Medium	0	1	Very low, low, medium					
0.7	1	3	Medium	0	0	Absent					
0.8	1	3	Medium	0	1	Very low, low, medium					
0.9	1	2	Low	1	1	Very low, low, medium					
1.0	0	1	Very Low	0	1	Very low, low, medium					
1.1	0	2	Low	0	0	Absent					
1.2	2	2	Low	0	0	Absent					
1.3	0	3	Medium	0	0	Absent					
1.4	1	2	Low	0	0	Absent					
1.5	1	2	Low	0	0	Absent					
1.6	0	5	High	0	2	High					
1.7	4	5	High	2	2	High					
1.8	1	6	Very high	0	2	High					
1.9	1	5	High	0	0	Absent					
2.0	3	4	High	0	0	Absent	15	3	18	27	Very high
2.1	0	3	Medium	0	0	Absent	9	0	9	30	Very high
2.2	0	1	Very Low	0	0	Absent	3	0	3	15	Medium
2.3	1	4	High	0	0	Absent	2	1	3	36	Very high
2.4	3	5	High	0	0	Absent	27	3	30	46	Very high
2.5	1	5	High	0	1	Very low, low, medium	12	1	13	52	Very high
2.6	1	4	High	1	2	High	8	1	9	41	Very high
2.7	2	5	High	1	2	High	17	2	19	46	Very high
2.8	2	6	Very high	0	1	Very low, low, medium	16	2	18	46	Very high
2.9	2	7	Very high	0	1	Very low, low, medium	7	2	9	32	Very high
3.0	3	6	Very high	1	1	Very low, low, medium	2	3	5	21	High
3.1	1	5	High	0	1	Very low, low, medium	6	1	7	20	High

3.2	1	4	High	0	0	Absent	7	1	8	20	High
3.3	2	4	High	0	0	Absent	3	2	5	15	Medium
3.4	1	5	High	0	1	Very low, low, medium	1	1	2	14	Medium
3.5	2	3	Medium	1	1	Very low, low, medium	5	2	7	11	Medium
3.6	0	5	High	0	1	Very low, low, medium	2	0	2	23	High
3.7	3	3	Medium	0	0	Absent	11	3	14	19	High
3.8	0	3	Medium	0	0	Absent	2	1	3	26	Very high
3.9	0	2	Low	0	1	Very low, low, medium	9	0	9	21	High
4.0	2	4	High	1	1	Very low, low, medium	7	2	9	22	High
4.1	2	6	Very high	0	2	High	2	2	4	17	High
4.2	2	6	Very high	1	1	Very low, low, medium	2	2	4	13	Medium
4.3	2	5	High	0	1	Very low, low, medium	3	2	5	13	Medium
4.4	1	5	High	0	1	Very low, low, medium	3	1	4	12	Medium
4.5	2	4	High	1	1	Very low, low, medium	1	2	3	12	Medium
4.6	1	5	High	0	2	High	4	1	5	14	Medium
4.7	2	3	Medium	1	1	Very low, low, medium	4	2	6	12	Medium
4.8	0	3	Medium	0	1	Very low, low, medium	1	0	1	10	Low
4.9	1	3	Medium	0	0	Absent	2	1	3	12	Medium
5.0	2	7	Very high	0	1	Very low, low, medium	6	2	8	17	High
5.1	4	7	Very high	1	1	Very low, low, medium	2	4	6	19	High
5.2	1	6	Very high	0	2	High	4	1	5	14	Medium
5.3	1	2	Low	1	1	Very low, low, medium	2	1	3	11	Medium
5.4	0	1	Very Low	0	1	Very low, low, medium	3	0	3	9	Low
5.5	0	0	Absent	0	0	Absent	3	0	3	11	Medium
5.6	0	1	Very Low	0	0	Absent	4	1	5	13	Medium
5.7	1	1	Very Low	0	0	Absent	4	1	5	10	Low

5.8	0	1	Very Low	0	0	Absent	0	0	0	7	Low
5.9	0	1	Very Low	0	0	Absent	2	0	2	4	Very low
6.0	1	2	Low	0	0	Absent	1	1	2	8	Low
6.1	1	3	Medium	0	0	Absent	3	1	4	10	Low
6.2	1	3	Medium	0	0	Absent	3	1	4	12	Medium
6.3	1	2	Low	0	0	Absent	3	1	4	9	Low
6.4	0	1	Very Low	0	0	Absent	1	0	1	5	Very low
6.5	0	0	Absent	0	0	Absent	0	0	0	4	Very low
6.6	0	0	Absent	0	0	Absent	3	0	3	3	Very low
6.7	0	2	Low	0	0	Absent	0	0	0	7	Low
6.8	2	4	High	0	0	Absent	2	2	4	8	Low
6.9	2	5	High	0	0	Absent	2	2	4	14	Medium
7.0	1	16	Very high	0	2	High	5	1	6	35	Very high
7.1	13	15	Very high	2	2	High	12	13	25	32	Very high
7.2	1	14	Very high	0	2	High	0	1	1	35	Very high
7.3	0	1	Very Low	0	0	Absent	9	0	9	11	Medium
7.4	0	0	Absent	0	0	Absent	1	0	1	10	Low
7.5	0	0	Absent	0	0	Absent	0	0	0	1	Very low
7.6	0	0	Absent	0	0	Absent	0	0	0	1	Very low
7.7	0	2	Low	0	0	Absent	0	1	1	6	Very low
7.8	2	3	Medium	0	0	Absent	3	2	5	11	Medium
7.9	1	3	Medium	0	0	Absent	4	1	5	14	Medium
8.0	0	2	Low	0	0	Absent	3	1	4	18	High
8.1	1	2	Low	0	0	Absent	8	1	9	19	High
8.2	1	2	Low	0	0	Absent	5	1	6	17	High
8.3	0	5	High	0	1	Very low, low, medium	2	0	2	19	High

8.4	4	5	High	1	1	Very low, low, medium	7	4	11	19	High
8.5	1	9	Very high	0	2	High	5	1	6	27	Very high
8.6	4	8	Very high	1	2	High	6	4	10	24	High
8.7	3	9	Very high	1	4	Very high	5	3	8	26	Very high
8.8	2	5	High	2	3	Very high	6	2	8	19	High
8.9	0	2	Low	0	2	High	3	0	3	17	High
9.0	0	0	Absent	0	0	Absent	6	0	6	9	Low
9.1	0	0	Absent	0	0	Absent	0	0	0	12	Medium
9.2	0	1	Very Low	0	0	Absent	6	0	6	8	Low
9.3	1	1	Very Low	0	0	Absent	1	1	2	10	Low
9.4	0	2	Low	0	0	Absent	2	0	2	7	Low
9.5	1	1	Very Low	0	0	Absent	2	1	3	5	Very low
9.6	0	2	Low	0	0	Absent	0	0	0	5	Very low
9.7	1	1	Very Low	0	0	Absent	1	1	2	2	Very low
9.8	0	3	Medium	0	1	Very low, low, medium	0	0	0	4	Very low
9.9	2	2	Low	1	1	Very low, low, medium	0	2	2	7	Low
10.0	0	3	Medium	0	2	High	5	0	5	11	Medium
10.1	1	2	Low	1	2	High	3	1	4	12	Medium
10.2	1	3	Medium	1	3	Very high	2	1	3	13	Medium
10.3	1	3	Medium	1	2	High	4	2	6	12	Medium
10.4	1	2	Low	0	1	Very low, low, medium	2	1	3	12	Medium
10.5	0	4	High	0	1	Very low, low, medium	3	0	3	13	Medium
10.6	3	4	High	1	1	Very low, low, medium	3	4	7	25	High
10.7	1	6	Very high	0	2	High	14	1	15	28	Very high
10.8	2	3	Medium	1	1	Very low, low, medium	4	2	6	29	Very high
10.9	0	3	Medium	0	2	High	8	0	8	19	High

11.0	1	2	Low	1	2	High	4	1	5	15	Medium
11.1	1	3	Medium	1	2	High	1	1	2	14	Medium
11.2	1	4	High	0	1	Very low, low, medium	6	1	7	13	Medium
11.3	2	3	Medium	0	0	Absent	2	2	4	22	High
11.4	0	3	Medium	0	0	Absent	10	1	11	26	Very high
11.5	1	1	Very Low	0	0	Absent	10	1	11	23	High
11.6	0	1	Very Low	0	0	Absent	1	0	1	38	Very high
11.7	0	1	Very Low	0	0	Absent	26	0	26	50	Very high
11.8	1	5	High	0	0	Absent	22	1	23	58	Very high
11.9	4	7	Very high	0	1	Very low, low, medium	5	4	9	38	Very high
12.0	2	7	Very high	1	2	High	4	2	6	21	High
12.1	1	4	High	1	2	High	5	1	6	17	High
12.2	1	3	Medium	0	1	Very low, low, medium	4	1	5	15	Medium
12.3	1	2	Low	0	0	Absent	3	1	4	9	Low
12.4	0	2	Low	0	0	Absent	0	0	0	7	Low
12.5	1	2	Low	0	0	Absent	2	1	3	8	Low
12.6	1	2	Low	0	0	Absent	4	1	5	12	Medium
12.7	0	2	Low	0	1	Very low, low, medium	4	0	4	13	Medium
12.8	1	1	Very Low	1	1	Very low, low, medium	3	1	4	8	Low
12.9	0	1	Very Low	0	1	Very low, low, medium	0	0	0	4	Very low
13.0	0	0	Absent	0	0	Absent	0	0	0	7	Low
13.1	0	1	Very Low	0	0	Absent	6	1	7	9	Low
13.2	1	1	Very Low	0	0	Absent	1	1	2	11	Medium
13.3	0	1	Very Low	0	0	Absent	1	1	2	7	Low
13.4	0	0	Absent	0	0	Absent	3	0	3	9	Low
13.5	0	0	Absent	0	0	Absent	4	0	4	10	Low

13.6	0	1	Very Low	0	0	Absent	3	0	3	10	Low
13.7	1	3	Medium	0	1	Very low, low, medium	2	1	3	9	Low
13.8	2	3	Medium	1	1	Very low, low, medium	1	2	3	13	Medium
13.9	0	3	Medium	0	1	Very low, low, medium	7	0	7	12	Medium
14.0	1	1	Very Low	0	0	Absent	1	1	2	9	Low
14.1	0	1	Very Low	0	0	Absent	0	0	0	5	Very low
14.2	0	1	Very Low	0	0	Absent	3	0	3	8	Low
14.3	1	2	Low	0	0	Absent	4	1	5	13	Medium
14.4	1	2	Low	0	0	Absent	4	1	5	13	Medium
14.5	0	2	Low	0	0	Absent	3	0	3	16	High
14.6	1	5	High	0	0	Absent	7	1	8	31	Very high
14.7	4	7	Very high	0	0	Absent	16	4	20	42	Very high
14.8	2	7	Very high	0	1	Very low, low, medium	11	3	14	37	Very high
14.9	1	5	High	1	3	Very high	2	1	3	27	Very high
15.0	2	3	Medium	2	3	Very high	8	2	10	18	High
15.1	0	3	Medium	0	2	High	4	1	5	20	High
15.2	1	1	Very Low	0	0	Absent	4	1	5	13	Medium
15.3	0	3	Medium	0	2	High	3	0	3	12	Medium
15.4	2	2	Low	2	2	High	1	3	4	8	Low
15.5	0	3	Medium	0	3	Very high	1	0	1	13	Medium
15.6	1	2	Low	1	2	High	7	1	8	11	Medium
15.7	1	2	Low	1	2	High	1	1	2	11	Medium
15.8	0	3	Medium	0	2	High	1	0	1	7	Low
15.9	2	2	Low	1	1	Very low, low, medium	2	2	4	5	Very low
16.0	0	3	Medium	0	2	High	0	0	0	6	Very low
16.1	1	3	Medium	1	2	High	1	1	2	7	Low

16.2	2	4	High	1	3	Very high	3	2	5	8	Low
16.3	1	3	Medium	1	2	High	0	1	1	6	Very low
16.4	0	1	Very Low	0	1	Very low, low, medium	0	0	0	3	Very low
16.5	0	0	Absent	0	0	Absent	2	0	2	4	Very low
16.6	0	0	Absent	0	0	Absent	2	0	2	5	Very low
16.7	0	0	Absent	0	0	Absent	1	0	1	5	Very low
16.8	0	0	Absent	0	0	Absent	2	0	2	4	Very low
16.9	0	1	Very Low	0	0	Absent	1	0	1	5	Very low
17.0	1	1	Very Low	0	0	Absent	1	1	2	4	Very low
17.1	0	3	Medium	0	1	Very low, low, medium	1	0	1	5	Very low
17.2	2	2	Low	1	1	Very low, low, medium	0	2	2	5	Very low
17.3	0	5	High	0	2	High	2	0	2	10	Low
17.4	3	3	Medium	1	1	Very low, low, medium	3	3	6	10	Low
17.5	0	4	High	0	1	Very low, low, medium	2	0	2	11	Medium
17.6	1	1	Very Low	0	0	Absent	1	2	3	7	Low
17.7	0	2	Low	0	1	Very low, low, medium	2	0	2	10	Low
17.8	1	2	Low	1	1	Very low, low, medium	4	1	5	17	High
17.9	1	2	Low	0	1	Very low, low, medium	9	1	10	22	High
18.0	0	2	Low	0	0	Absent	7	0	7	28	Very high
18.1	1	2	Low	0	1	Very low, low, medium	10	1	11	26	Very high
18.2	1	3	Medium	1	1	Very low, low, medium	7	1	8	29	Very high
18.3	1	5	High	0	1	Very low, low, medium	7	3	10	47	Very high
18.4	3	7	Very high	0	1	Very low, low, medium	25	4	29	51	Very high
18.5	3	7	Very high	1	2	High	9	3	12	49	Very high
18.6	1	7	Very high	1	3	Very high	7	1	8	25	High
18.7	3	4	High	1	2	High	2	3	5	24	High

18.8	0	3	Medium	0	1	Very low, low, medium	11	0	11	16	High
18.9	0	2	Low	0	1	Very low, low, medium	0	0	0	17	High
19.0	2	2	Low	1	1	Very low, low, medium	4	2	6	11	Medium
19.1	0	3	Medium	0	2	High	5	0	5	15	Medium
19.2	1	1	Very Low	1	1	Very low, low, medium	2	2	4	22	High
19.3	0	3	Medium	0	2	High	12	1	13	28	Very high
19.4	2	3	Medium	1	1	Very low, low, medium	9	2	11	33	Very high
19.5	1	4	High	0	1	Very low, low, medium	8	1	9	22	High
19.6	1	3	Medium	0	0	Absent	1	1	2	12	Medium
19.7	1	5	High	0	1	Very low, low, medium	0	1	1	12	Medium
19.8	3	5	High	1	1	Very low, low, medium	6	3	9	18	High
19.9	1	5	High	0	2	High	7	1	8	21	High
20.0	1	3	Medium	1	2	High	3	1	4	31	Very high
20.1	1	3	Medium	1	3	Very high	18	1	19	26	Very high
20.2	1	3	Medium	1	3	Very high	2	1	3	26	Very high
20.3	1	4	High	1	3	Very high	3	1	4	14	Medium
20.4	2	3	Medium	1	2	High	4	3	7	15	Medium
20.5	0	4	High	0	3	Very high	4	0	4	14	Medium
20.6	2	5	High	2	3	Very high	1	2	3	11	Medium
20.7	3	6	Very high	1	4	Very high	1	3	4	10	Low
20.8	1	4	High	1	2	High	1	2	3	7	Low
20.9	0	2	Low	0	1	Very low, low, medium	0	0	0	7	Low
21.0	1	2	Low	0	1	Very low, low, medium	3	1	4	10	Low
21.1	1	2	Low	1	1	Very low, low, medium	4	2	6	11	Medium
21.2	0	2	Low	0	1	Very low, low, medium	1	0	1	13	Medium
21.3	1	5	High	0	2	High	5	1	6	20	High

21.4	4	6	Very high	2	2	High	9	4	13	27	Very high
21.5	1	6	Very high	0	3	Very high	6	2	8	26	Very high
21.6	1	2	Low	1	1	Very low, low, medium	4	1	5	16	High
21.7	0	3	Medium	0	2	High	2	1	3	12	Medium
21.8	2	2	Low	1	1	Very low, low, medium	2	2	4	8	Low
21.9	0	2	Low	0	1	Very low, low, medium	1	0	1	9	Low
22.0	0	2	Low	0	0	Absent	4	0	4	20	High
22.1	2	4	High	0	0	Absent	13	2	15	23	High
22.2	2	5	High	0	0	Absent	2	2	4	25	High
22.3	1	5	High	0	1	Very low, low, medium	4	2	6	13	Medium
22.4	2	3	Medium	1	1	Very low, low, medium	1	2	3	17	High
22.5	0	3	Medium	0	1	Very low, low, medium	6	2	8	15	Medium
22.6	1	2	Low	0	0	Absent	3	1	4	16	High
22.7	1	2	Low	0	0	Absent	3	1	4	8	Low
22.8	0	1	Very Low	0	0	Absent	0	0	0	8	Low
22.9	0	1	Very Low	0	1	Very low, low, medium	2	2	4	6	Very low
23.0	1	4	High	1	2	High	1	1	2	39	Very high
23.1	3	8	Very high	1	4	Very high	30	3	33	45	Very high
23.2	4	11	Very high	2	4	Very high	5	5	10	51	Very high
23.3	4	10	Very high	1	3	Very high	4	4	8	28	Very high
23.4	2	6	Very high	0	1	Very low, low, medium	7	3	10	20	High
23.5	0	3	Medium	0	0	Absent	2	0	2	15	Medium
23.6	1	1	Very Low	0	0	Absent	2	1	3	8	Low
23.7	0	3	Medium	0	0	Absent	3	0	3	16	High
23.8	2	2	Low	0	0	Absent	8	2	10	13	Medium
23.9	0	3	Medium	0	0	Absent	0	0	0	18	High

24.0	1	3	Medium	0	1	Very low, low, medium	6	2	8	26	Very high
24.1	2	3	Medium	1	1	Very low, low, medium	16	2	18	27	Very high
24.2	0	2	Low	0	1	Very low, low, medium	1	0	1	19	High
24.3	0	1	Very Low	0	0	Absent	0	0	0	5	Very low
24.4	1	2	Low	0	0	Absent	3	1	4	8	Low
24.5	1	2	Low	0	0	Absent	3	1	4	13	Medium
24.6	0	1	Very Low	0	0	Absent	5	0	5	11	Medium
24.7	0	3	Medium	0	2	High	2	0	2	11	Medium
24.8	3	4	High	2	2	High	1	3	4	10	Low
24.9	1	4	High	0	2	High	3	1	4	9	Low
25.0	0	2	Low	0	1	Very low, low, medium	1	0	1	10	Low
25.1	1	1	Very Low	1	1	Very low, low, medium	4	1	5	22	High
25.2	0	2	Low	0	1	Very low, low, medium	16	0	16	23	High
25.3	1	2	Low	0	1	Very low, low, medium	1	1	2	20	High
25.4	1	3	Medium	1	1	Very low, low, medium	1	1	2	9	Low
25.5	1	4	High	0	1	Very low, low, medium	3	2	5	14	Medium
25.6	2	7	Very high	0	3	Very high	5	2	7	19	High
25.7	4	6	Very high	3	3	Very high	3	4	7	15	Medium
25.8	0	6	Very high	0	4	Very high	1	0	1	10	Low
25.9	2	4	High	1	1	Very low, low, medium	0	2	2	8	Low
26.0	2	4	High	0	1	Very low, low, medium	3	2	5	12	Medium
26.1	0	4	High	0	1	Very low, low, medium	5	0	5	21	High
26.2	2	5	High	1	1	Very low, low, medium	9	2	11	28	Very high
26.3	3	15	Very high	0	3	Very high	9	3	12	61	Very high
26.4	10	22	Very high	2	4	Very high	28	10	38	74	Very high
26.5	9	28	Very high	2	8	Very high	15	9	24	77	Very high

26.6	9	21	Very high	4	7	Very high	6	9	15	54	Very high
26.7	3	15	Very high	1	5	Very high	12	3	15	41	Very high
26.8	3	6	Very high	0	1	Very low, low, medium	8	3	11	32	Very high
26.9	0	3	Medium	0	0	Absent	6	0	6	26	Very high
27.0	0	1	Very low	0	1	Very low, low, medium	8	1	9	19	High
27.1	1	4	High	1	3	Very high	2	2	4	17	High
27.2	3	8	Very high	2	5	Very high	1	3	4	20	High
27.3	4	9	Very high	2	4	Very high	8	4	12	38	Very high
27.4	2	6	Very high	0	2	High	20	2	22	36	Very high
27.5	0	7	Very high	0	1	Very low, low, medium	2	0	2	32	Very high
27.6	5	6	Very high	1	1	Very low, low, medium	3	5	8	13	Medium
27.7	1	7	Very high	0	2	High	2	1	3	12	Medium
27.8	1	3	Medium	1	2	High	0	1	1	8	Low
27.9	1	3	Medium	1	2	High	2	2	4	6	Very low
28.0	1	3	Medium	0	1	Very low, low, medium	0	1	1	8	Low
28.1	1	2	Low	0	0	Absent	2	1	3	6	Very low
28.2	0	2	Low	0	0	Absent	2	0	2	9	Low
28.3	1	2	Low	0	0	Absent	3	1	4	11	Medium
28.4	1	5	High	0	2	High	4	1	5	15	Medium
28.5	3	4	High	2	2	High	3	3	6	13	Medium
28.6	0	4	High	0	3	Very high	2	0	2	12	Medium
28.7	1	3	Medium	1	2	High	3	1	4	9	Low
28.8	2	4	High	1	3	Very high	1	2	3	9	Low
28.9	1	3	Medium	1	2	High	1	1	2	7	Low
29.0	0	2	Low	0	1	Very low, low, medium	2	0	2	10	Low
29.1	1	2	Low	0	1	Very low, low, medium	5	1	6	9	Low

29.2	1	5	High	1	2	High	0	1	1	11	Medium
29.3	3	4	High	1	2	High	1	3	4	9	Low
29.4	0	4	High	0	2	High	4	0	4	12	Medium
29.5	1	1	Very Low	1	1	Very low, low, medium	2	2	4	17	High
29.6	0	2	Low	0	1	Very low, low, medium	9	0	9	14	Medium
29.7	1	2	Low	0	1	Very low, low, medium	0	1	1	16	High
29.8	1	2	Low	1	1	Very low, low, medium	5	1	6	10	Low
29.9	0	2	Low	0	1	Very low, low, medium	3	0	3	11	Medium
30.0	1	1	Very Low	0	0	Absent	1	1	2	8	Low
30.1	0	1	Very Low	0	0	Absent	3	0	3	8	Low
30.2	0	1	Very Low	0	0	Absent	3	0	3	9	Low
30.3	1	2	Low	0	0	Absent	2	1	3	10	Low
30.4	1	3	Medium	0	0	Absent	3	1	4	12	Medium
30.5	1	2	Low	0	0	Absent	4	1	5	12	Medium
30.6	0	3	Medium	0	0	Absent	3	0	3	12	Medium
30.7	2	3	Medium	0	1	Very low, low, medium	1	3	4	8	Low
30.8	1	3	Medium	1	1	Very low, low, medium	0	1	1	6	Very low
30.9	0	3	Medium	0	3	Very high	0	1	1	4	Very low
31.0	2	2	Low	2	2	High	0	2	2	6	Very low
31.1	0	2	Low	0	2	High	3	0	3	7	Low
31.2	0	1	Very Low	0	1	Very low, low, medium	2	0	2	6	Very low
31.3	1	3	Medium	1	1	Very low, low, medium	0	1	1	7	Low
31.4	2	7	Very high	0	1	Very low, low, medium	2	2	4	14	Medium
31.5	4	8	Very high	0	0	Absent	5	4	9	16	High
31.6	2	7	Very high	0	1	Very low, low, medium	0	3	3	15	Medium
31.7	1	3	Medium	1	1	Very low, low, medium	2	1	3	6	Very low

31.8	0	2	Low	0	1	Very low, low, medium	0	0	0	7	Low
31.9	1	1	Very Low	0	0	Absent	3	1	4	8	Low
32.0	0	2	Low	0	0	Absent	4	0	4	11	Medium
32.1	1	2	Low	0	0	Absent	2	1	3	17	High
32.2	1	4	High	0	0	Absent	8	2	10	27	Very high
32.3	2	4	High	0	1	Very low, low, medium	12	2	14	32	Very high
32.4	1	6	Very high	1	2	High	7	1	8	30	Very high
32.5	3	6	Very high	1	4	Very high	5	3	8	23	High
32.6	2	7	Very high	2	4	Very high	4	3	7	24	High
32.7	2	9	Very high	1	3	Very high	7	2	9	28	Very high
32.8	5	8	Very high	0	2	High	7	5	12	29	Very high
32.9	1	8	Very high	1	2	High	6	2	8	32	Very high
33.0	2	6	Very high	1	3	Very high	10	2	12	29	Very high
33.1	3	5	High	1	2	High	6	3	9	25	High
33.2	0	9	Very high	0	2	High	3	1	4	49	Very high
33.3	6	9	Very high	1	2	High	29	7	36	57	Very high
33.4	3	10	Very high	1	2	High	14	3	17	70	Very high
33.5	1	10	Very high	0	5	Very high	15	2	17	61	Very high
33.6	6	10	Very high	4	6	Very high	21	6	27	59	Very high
33.7	3	12	Very high	2	6	Very high	11	4	15	51	Very high
33.8	3	6	Very high	0	2	High	6	3	9	28	Very high
33.9	0	6	Very high	0	2	High	4	0	4	23	High
34.0	3	6	Very high	2	2	High	6	4	10	23	High
34.1	3	7	Very high	0	3	Very high	6	3	9	53	Very high
34.2	1	5	High	1	2	High	33	1	34	50	Very high
34.3	1	5	High	1	2	High	6	1	7	53	Very high

34.4	3	8	Very high	0	2	High	9	3	12	29	Very high
34.5	4	10	Very high	1	2	High	6	4	10	29	Very high
34.6	3	8	Very high	1	2	High	4	3	7	27	Very high
34.7	1	12	Very high	0	4	Very high	9	1	10	30	Very high
34.8	8	10	Very high	3	3	Very high	5	8	13	35	Very high
34.9	1	13	Very high	0	4	Very high	11	1	12	35	Very high
35.0	4	16	Very high	1	2	High	6	4	10	53	Very high
35.1	11	26	Very high	1	7	Very high	18	13	31	66	Very high
35.2	11	27	Very high	5	6	Very high	13	12	25	62	Very high
35.3	5	20	Very high	0	6	Very high	1	5	6	41	Very high
35.4	4	12	Very high	1	3	Very high	6	4	10	26	Very high
35.5	3	9	Very high	2	4	Very high	7	3	10	27	Very high
35.6	2	10	Very high	1	6	Very high	4	3	7	25	High
35.7	5	11	Very high	3	5	Very high	3	5	8	24	High
35.8	4	12	Very high	1	5	Very high	5	4	9	23	High
35.9	3	9	Very high	1	4	Very high	3	3	6	20	High
36.0	2	8	Very high	2	5	Very high	3	2	5	15	Medium
36.1	3	9	Very high	2	6	Very high	1	3	4	24	High
36.2	4	10	Very high	2	6	Very high	11	4	15	26	Very high
36.3	3	13	Very high	2	7	Very high	4	3	7	34	Very high
36.4	6	10	Very high	3	5	Very high	6	6	12	22	High
36.5	1	11	Very high	0	4	Very high	2	1	3	21	High
36.6	4	10	Very high	1	1	Very low, low, medium	2	4	6	20	High
36.7	5	12	Very high	0	2	High	6	5	11	26	Very high
36.8	3	12	Very high	1	2	High	6	3	9	40	Very high
36.9	4	10	Very high	1	3	Very high	16	4	20	44	Very high

37.0	3	10	Very high	1	4	Very high	12	3	15	42	Very high
37.1	3	12	Very high	2	5	Very high	4	3	7	44	Very high
37.2	6	13	Very high	2	5	Very high	16	6	22	40	Very high
37.3	4	13	Very high	1	6	Very high	7	4	11	40	Very high
37.4	3	10	Very high	3	7	Very high	3	4	7	28	Very high
37.5	3	8	Very high	3	7	Very high	7	3	10	24	High
37.6	2	6	Very high	1	5	Very high	5	2	7	22	High
37.7	1	5	High	1	2	High	4	1	5	15	Medium
37.8	2	5	High	0	1	Very low, low, medium	1	2	3	13	Medium
37.9	2	4	High	0	0	Absent	3	2	5	9	Low
38.0	0	3	Medium	0	0	Absent	1	0	1	10	Low
38.1	1	2	Low	0	0	Absent	3	1	4	21	High
38.2	1	4	High	0	1	Very low, low, medium	15	1	16	30	Very high
38.3	2	3	Medium	1	1	Very low, low, medium	8	2	10	29	Very high
38.4	0	2	Low	0	1	Very low, low, medium	3	0	3	14	Medium
38.5	0	1	Very Low	0	1	Very low, low, medium	1	0	1	8	Low
38.6	1	2	Low	1	1	Very low, low, medium	3	1	4	10	Low
38.7	1	4	High	0	2	High	4	1	5	13	Medium
38.8	2	4	High	1	2	High	2	2	4	14	Medium
38.9	1	7	Very high	1	4	Very high	4	1	5	27	Very high
39.0	4	6	Very high	2	3	Very high	14	4	18	25	High
39.1	1	7	Very high	0	3	Very high	1	1	2	36	Very high
39.2	2	5	High	1	2	High	14	2	16	22	High
39.3	2	5	High	1	3	Very high	2	2	4	23	High
39.4	1	4	High	1	3	Very high	2	1	3	11	Medium
39.5	1	3	Medium	1	2	High	3	1	4	12	Medium

39.6	1	2	Low	0	1	Very low, low, medium	4	1	5	10	Low
39.7	0	3	Medium	0	0	Absent	1	0	1	10	Low
39.8	2	3	Medium	0	0	Absent	2	2	4	8	Low
39.9	1	6	Very high	0	1	Very low, low, medium	2	1	3	16	High
40.0	3	14	Very high	1	5	Very high	6	3	9	31	Very high
40.1	10	20	Very high	4	8	Very high	9	10	19	49	Very high
40.2	7	21	Very high	3	8	Very high	14	7	21	46	Very high
40.3	4	14	Very high	1	6	Very high	2	4	6	34	Very high
40.4	3	9	Very high	2	4	Very high	4	3	7	21	High
40.5	2	10	Very high	1	5	Very high	6	2	8	24	High
40.6	5	14	Very high	2	7	Very high	4	5	9	31	Very high
40.7	7	14	Very high	4	7	Very high	7	7	14	30	Very high
40.8	2	12	Very high	1	8	Very high	5	2	7	27	Very high
40.9	3	7	Very high	3	4	Very high	3	3	6	23	High
41.0	2	6	Very high	0	3	Very high	7	3	10	23	High
41.1	1	15	Very high	0	6	Very high	6	1	7	44	Very high
41.2	12	16	Very high	6	7	Very high	14	13	27	38	Very high
41.3	3	15	Very high	1	7	Very high	0	4	4	34	Very high
41.4	0	5	High	0	2	High	3	0	3	12	Medium
41.5	2	8	Very high	1	2	High	3	2	5	20	High
41.6	6	9	Very high	1	3	Very high	6	6	12	21	High
41.7	1	9	Very high	1	4	Very high	2	2	4	23	High
41.8	2	7	Very high	2	4	Very high	5	2	7	19	High
41.9	4	14	Very high	1	3	Very high	3	5	8	27	Very high
42.0	8	18	Very high	0	2	High	3	9	12	46	Very high
42.1	6	23	Very high	1	3	Very high	18	8	26	75	Very high

42.2	9	16	Very high	2	4	Very high	28	9	37	67	Very high
42.3	1	13	Very high	1	5	Very high	3	1	4	47	Very high
42.4	3	9	Very high	2	3	Very high	3	3	6	23	High
42.5	5	10	Very high	0	3	Very high	8	5	13	24	High
42.6	2	8	Very high	1	1	Very low, low, medium	3	2	5	21	High
42.7	1	3	Medium	0	1	Very low, low, medium	2	1	3	12	Medium
42.8	0	1	Very Low	0	0	Absent	4	0	4	10	Low
42.9	0	1	Very Low	0	1	Very low, low, medium	3	0	3	11	Medium
43.0	1	2	Low	1	2	High	2	2	4	21	High
43.1	1	2	Low	1	2	High	13	1	14	22	High
43.2	0	2	Low	0	1	Very low, low, medium	4	0	4	29	Very high
43.3	1	5	High	0	0	Absent	9	2	11	36	Very high
43.4	4	11	Very high	0	0	Absent	16	5	21	51	Very high
43.5	6	11	Very high	0	1	Very low, low, medium	12	7	19	45	Very high
43.6	1	8	Very high	1	1	Very low, low, medium	4	1	5	27	Very high
43.7	1	2	Low	0	1	Very low, low, medium	2	1	3	11	Medium
43.8	0	1	Very Low	0	0	Absent	3	0	3	9	Low
43.9	0	1	Very Low	0	0	Absent	2	1	3	7	Low
44.0	1	1	Very Low	0	0	Absent	0	1	1	7	Low
44.1	0	5	High	0	3	Very high	3	0	3	8	Low
44.2	4	5	High	3	3	Very high	0	4	4	8	Low
44.3	1	6	Very high	0	3	Very high	0	1	1	10	Low
44.4	1	3	Medium	0	1	Very low, low, medium	4	1	5	11	Medium
44.5	1	2	Low	1	1	Very low, low, medium	4	1	5	15	Medium
44.6	0	2	Low	0	2	High	5	0	5	16	High
44.7	1	3	Medium	1	3	Very high	5	1	6	16	High

44.8	2	5	High	2	5	Very high	3	2	5	14	Medium
44.9	2	4	High	2	4	Very high	1	2	3	9	Low
45.0	0	4	High	0	2	High	0	1	1	17	High
45.1	2	6	Very high	0	1	Very low, low, medium	11	2	13	25	High
45.2	4	7	Very high	1	2	High	7	4	11	27	Very high
45.3	1	7	Very high	1	3	Very high	1	2	3	21	High
45.4	2	4	High	1	2	High	4	3	7	19	High
45.5	1	3	Medium	0	1	Very low, low, medium	8	1	9	21	High
45.6	0	6	Very high	0	2	High	5	0	5	25	High
45.7	5	5	High	2	2	High	6	5	11	16	High
45.8	0	7	Very high	0	2	High	0	0	0	16	High
45.9	2	5	High	0	2	High	3	2	5	14	Medium
46.0	3	5	High	2	2	High	6	3	9	14	Medium
46.1	0	10	Very high	0	5	Very high	0	0	0	38	Very high
46.2	7	10	Very high	3	3	Very high	21	8	29	33	Very high
46.3	3	11	Very high	0	3	Very high	1	3	4	35	Very high
46.4	1	7	Very high	0	1	Very low, low, medium	1	1	2	10	Low
46.5	3	4	High	1	1	Very low, low, medium	1	3	4	6	Very low
46.6	0	3	Medium	0	1	Very low, low, medium	0	0	0	4	Very low
46.7	0	1	Very Low	0	0	Absent	0	0	0	4	Very low
46.8	1	1	Very Low	0	0	Absent	3	1	4	10	Low
46.9	0	2	Low	0	0	Absent	6	0	6	15	Medium
47.0	1	4	High	0	0	Absent	4	1	5	30	Very high
47.1	3	6	Very high	0	0	Absent	16	3	19	60	Very high
47.2	2	5	High	0	0	Absent	33	3	36	63	Very high
47.3	0	2	Low	0	0	Absent	8	0	8	45	Very high

47.4	0	3	Medium	0	0	Absent	1	0	1	21	High
47.5	3	3	Medium	0	0	Absent	9	3	12	16	High
47.6	0	3	Medium	0	0	Absent	3	0	3	19	High
47.7	0	1	Very Low	0	0	Absent	3	1	4	10	Low
47.8	1	1	Very Low	0	0	Absent	2	1	3	7	Low
47.9	0	2	Low	0	0	Absent	0	0	0	6	Very low
48.0	1	2	Low	0	0	Absent	2	1	3	5	Very low
48.1	1	2	Low	0	0	Absent	1	1	2	7	Low
48.2	0	1	Very Low	0	0	Absent	2	0	2	4	Very low
48.3	0	1	Very Low	0	1	Very low, low, medium					
48.4	1	2	Low	1	1	Very low, low, medium					
48.5	1	3	Medium	0	1	Very low, low, medium					
48.6	1	4	High	0	1	Very low, low, medium					
48.7	2	3	Medium	1	1	Very low, low, medium					
48.8	0	2	Low	0	1	Very low, low, medium					
48.9	0	2	Low	0	0	Absent					
49.0	2	3	Medium	0	0	Absent					
49.1	1	3	Medium	0	0	Absent					
49.2	0	4	High	0	0	Absent					
49.3	3	4	High	0	1	Very low, low, medium					
49.4	1	5	High	1	1	Very low, low, medium					
49.5	1	2	Low	0	1	Very low, low, medium					
49.6	0	1	Very Low	0	0	Absent					
49.7	0	1	Very Low	0	1	Very low, low, medium					
49.8	1	1	Very Low	1	1	Very low, low, medium					
49.9	0	2	Low	0	1	Very low, low, medium					

50.0	1	1	Very Low	0	0	Absent					
50.1	0	1	Very Low	0	0	Absent					
50.2	0	0	Absent	0	0	Absent					
50.3	0	0	Absent	0	0	Absent					
50.4	0	0	Absent	0	0	Absent					
50.5	0	0	Absent	0	0	Absent					
50.6	0	0	Absent	0	0	Absent					
50.7	0	0	Absent	0	0	Absent					
50.8	0	0	Absent	0	0	Absent					
50.9	0	0	Absent	0	0	Absent					
51.0	0	2	Low	0	1	Very low, low, medium					
51.1	2	2	Low	1	1	Very low, low, medium					
51.2	0	2	Low	0	1	Very low, low, medium					
51.3	0	0	Absent	0	0	Absent					
51.4	0	0	Absent	0	0	Absent					
51.5	0	0	Absent	0	0	Absent					
51.6	0	3	Medium	0	0	Absent					
51.7	3	3	Medium	0	0	Absent					
51.8	0	3	Medium	0	0	Absent					
51.9	0	1	Very Low	0	0	Absent					
52.0	1	1	Very Low	0	0	Absent					
52.1	0	2	Low	0	0	Absent	1	0	1	14	Medium
52.2	1	2	Low	0	1	Very low, low, medium	12	1	13	15	Medium
52.3	1	3	Medium	1	1	Very low, low, medium	0	1	1	15	Medium
52.4	1	2	Low	0	1	Very low, low, medium	0	1	1	2	Very low
52.5	0	2	Low	0	0	Absent	0	0	0	6	Very low

52.6	1	2	Low	0	1	Very low, low, medium	3	2	5	14	Medium
52.7	1	3	Medium	1	1	Very low, low, medium	8	1	9	19	High
52.8	1	2	Low	0	1	Very low, low, medium	4	1	5	14	Medium
52.9	0	1	Very Low	0	0	Absent	0	0	0	5	Very low
53.0	0	3	Medium	0	2	High	0	0	0	15	Medium
53.1	3	4	High	2	3	Very high	12	3	15	17	High
53.2	1	7	Very high	1	4	Very high	1	1	2	21	High
53.3	3	5	High	1	3	Very high	1	3	4	8	Low
53.4	1	5	High	1	3	Very high	1	1	2	9	Low
53.5	1	2	Low	1	2	High	2	1	3	5	Very low
53.6	0	1	Very Low	0	1	Very low, low, medium	0	0	0	3	Very low
53.7	0	0	Absent	0	0	Absent	0	0	0	0	Absent
53.8	0	1	Very Low	0	0	Absent	0	0	0	1	Very low
53.9	1	1	Very Low	0	0	Absent	0	1	1	1	Very low
54.0	0	1	Very Low	0	0	Absent	0	0	0	1	Very low
54.1	0	2	Low	0	2	High	0	0	0	3	Very low
54.2	2	2	Low	2	2	High	1	2	3	6	Very low
54.3	0	2	Low	0	2	High	3	0	3	6	Very low
54.4	0	3	Medium	0	2	High	0	0	0	13	Medium
54.5	3	4	High	2	3	Very high	6	3	9	12	Medium
54.6	1	4	High	1	3	Very high	1	1	2	14	Medium
54.7	0	2	Low	0	1	Very low, low, medium	2	0	2	8	Low
54.8	1	1	Very Low	0	0	Absent	3	1	4	7	Low
54.9	0	1	Very Low	0	0	Absent	1	0	1	19	High
55.0	0	2	Low	0	0	Absent	14	0	14	21	High
55.1	2	3	Medium	0	1	Very low, low, medium	4	2	6	25	High

55.2	1	6	Very high	1	3	Very high	4	1	5	15	Medium
55.3	3	7	Very high	2	4	Very high	1	3	4	16	High
55.4	3	7	Very high	1	4	Very high	4	3	7	12	Medium
55.5	1	4	High	1	2	High	0	1	1	8	Low
55.6	0	2	Low	0	2	High	0	0	0	4	Very low
55.7	1	2	Low	1	1	Very low, low, medium	1	1	2	6	Very low
55.8	1	4	High	0	2	High	2	1	3	9	Low
55.9	2	3	Medium	1	1	Very low, low, medium	1	2	3	10	Low
56.0	0	2	Low	0	1	Very low, low, medium	4	0	4	7	Low
56.1	0	0	Absent	0	0	Absent	0	0	0	5	Very low
56.2	0	1	Very Low	0	0	Absent	1	0	1	7	Low
56.3	1	1	Very Low	0	0	Absent	5	1	6	9	Low
56.4	0	1	Very Low	0	0	Absent	1	1	2	11	Medium
56.5	0	0	Absent	0	0	Absent	3	0	3	5	Very low
56.6	0	1	Very Low	0	1	Very low, low, medium					
56.7	1	2	Low	1	2	High					
56.8	1	3	Medium	1	2	High					
56.9	1	3	Medium	0	1	Very low, low, medium					
57.0	1	4	High	0	2	High					
57.1	2	4	High	2	2	High					
57.2	1	3	Medium	0	2	High					
57.3	0	1	Very Low	0	0	Absent					
57.4	0	0	Absent	0	0	Absent					
57.5	0	2	Low	0	1	Very low, low, medium					
57.6	2	2	Low	1	1	Very low, low, medium					
57.7	0	4	High	0	2	High					

57.8	2	3	Medium	1	2	High					
57.9	1	4	High	1	3	Very high					
58.0	1	3	Medium	1	3	Very high					
58.1	1	2	Low	1	2	High					
58.2	0	1	Very Low	0	1	Very low, low, medium					
58.3	0	0	Absent	0	0	Absent					
58.4	0	0	Absent	0	0	Absent					
58.5	0	1	Very Low	0	1	Very low, low, medium					
58.6	1	1	Very Low	1	1	Very low, low, medium					
58.7	0	1	Very Low	0	1	Very low, low, medium					
58.8	0	0	Absent	0	0	Absent					
58.9	0	1	Very Low	0	0	Absent					
59.0	1	3	Medium	0	0	Absent					
59.1	2	3	Medium	0	0	Absent					
59.2	0	2	Low	0	0	Absent					
59.3	0	0	Absent	0	0	Absent					
59.4	0	2	Low	0	1	Very low, low, medium					
59.5	2	2	Low	1	1	Very low, low, medium					
59.6	0	3	Medium	0	1	Very low, low, medium					
59.7	1	2	Low	0	1	Very low, low, medium					
59.8	1	2	Low	1	1	Very low, low, medium					
59.9	0	4	High	0	3	Very high					
60.0	3	4	High	2	3	Very high					
60.1	1	4	High	1	3	Very high					
60.2	0	1	Very Low	0	1	Very low, low, medium					
60.3	0	0	Absent	0	0	Absent					

60.4	0	3	Medium	0	2	High					
60.5	3	3	Medium	2	2	High	0	3	3	3	Very low
60.6	0	3	Medium	0	2	High	0	0	0	3	Very low
60.7	0	1	Very Low	0	0	Absent	0	0	0	1	Very low
60.8	1	2	Low	0	1	Very low, low, medium	0	1	1	2	Very low
60.9	1	3	Medium	1	2	High	0	1	1	3	Very low
61.0	1	2	Low	1	2	High	0	1	1	2	Very low
61.1	0	2	Low	0	2	High	0	0	0	3	Very low
61.2	1	1	Very Low	1	1	Very low, low, medium	1	1	2	3	Very low
61.3	0	4	High	0	1	Very low, low, medium	1	0	1	9	Low
61.4	3	3	Medium	0	0	Absent	3	3	6	9	Low
61.5	0	5	High	0	0	Absent	2	0	2	13	Medium
61.6	2	4	High	0	1	Very low, low, medium	3	2	5	13	Medium
61.7	2	6	Very high	1	2	High	3	3	6	14	Medium
61.8	2	4	High	1	2	High	1	2	3	10	Low
61.9	0	2	Low	0	1	Very low, low, medium	1	0	1	5	Very low
62.0	0	1	Very Low	0	0	Absent	0	1	1	10	Low
62.1	1	4	High	0	1	Very low, low, medium	6	2	8	14	Medium
62.2	3	4	High	1	1	Very low, low, medium	1	4	5	14	Medium
62.3	0	3	Medium	0	1	Very low, low, medium	1	0	1	6	Very low
62.4	0	1	Very Low	0	0	Absent	0	0	0	3	Very low
62.5	1	2	Low	0	0	Absent	1	1	2	4	Very low
62.6	1	3	Medium	0	1	Very low, low, medium	1	1	2	6	Very low
62.7	1	4	High	1	1	Very low, low, medium	1	1	2	11	Medium
62.8	2	3	Medium	0	1	Very low, low, medium	5	2	7	9	Low
62.9	0	2	Low	0	0	Absent					

63.0	0	1	Very Low	0	0	Absent					
63.1	1	1	Very Low	0	0	Absent					
63.2	0	3	Medium	0	1	Very low, low, medium					
63.3	2	2	Low	1	1	Very low, low, medium					
63.4	0	2	Low	0	1	Very low, low, medium					
63.5	0	0	Absent	0	0	Absent					
63.6	0	0	Absent	0	0	Absent					
63.7	0	0	Absent	0	0	Absent					
63.8	0	1	Very Low	0	0	Absent					
63.9	1	1	Very Low	0	0	Absent					
64.0	0	1	Very Low	0	0	Absent					
64.1	0	2	Low	0	0	Absent					
64.2	2	4	High	0	2	High					
64.3	2	4	High	2	2	High					
64.4	0	3	Medium	0	2	High					
64.5	1	2	Low	0	1	Very low, low, medium					
64.6	1	2	Low	1	1	Very low, low, medium					
64.7	0	1	Very Low	0	1	Very low, low, medium					
64.8	0	2	Low	0	1	Very low, low, medium					
64.9	2	3	Medium	1	1	Very low, low, medium					
65.0	1	3	Medium	0	1	Very low, low, medium					
65.1	0	3	Medium	0	1	Very low, low, medium					
65.2	2	3	Medium	1	1	Very low, low, medium					
65.3	1	3	Medium	0	1	Very low, low, medium					
65.4	0	1	Very Low	0	0	Absent					
65.5	0	0	Absent	0	0	Absent					

65.6	0	0	Absent	0	0	Absent					
65.7	0	0	Absent	0	0	Absent					
65.8	0	0	Absent	0	0	Absent					
65.9	0	1	Very Low	0	0	Absent					
66.0	1	1	Very Low	0	0	Absent					
66.1	0	3	Medium	0	1	Very low, low, medium					
66.2	2	2	Low	1	1	Very low, low, medium					
66.3	0	3	Medium	0	1	Very low, low, medium					
66.4	1	3	Medium	0	1	Very low, low, medium					
66.5	2	4	High	1	1	Very low, low, medium					
66.6	1	4	High	0	2	High					
66.7	1	4	High	1	2	High					
66.8	2	5	High	1	3	Very high					
66.9	2	4	High	1	2	High					
67.0	0	3	Medium	0	2	High					
67.1	1	1	Very Low	1	1	Very low, low, medium					
67.2	0	1	Very Low	0	1	Very low, low, medium					
67.3	0	0	Absent	0	0	Absent					
67.4	0	1	Very Low	0	1	Very low, low, medium					
67.5	1	1	Very Low	1	1	Very low, low, medium					
67.6	0	1	Very Low	0	1	Very low, low, medium					
67.7	0	1	Very Low	0	0	Absent					
67.8	1	2	Low	0	0	Absent					
67.9	1	3	Medium	0	0	Absent					
68.0	1	3	Medium	0	1	Very low, low, medium					
68.1	1	2	Low	1	1	Very low, low, medium					

68.2	0	2	Low	0	1	Very low, low, medium					
68.3	1	1	Very Low	0	0	Absent					
68.4	0	2	Low	0	1	Very low, low, medium					
68.5	1	1	Very Low	1	1	Very low, low, medium					
68.6	0	1	Very Low	0	1	Very low, low, medium					
68.7	0	0	Absent	0	0	Absent					
68.8	0	0	Absent	0	0	Absent					
68.9	0	0	Absent	0	0	Absent					
69.0	0	1	Very Low	0	0	Absent					
69.1	1	2	Low	0	0	Absent					
69.2	1	2	Low	0	0	Absent					
69.3	0	2	Low	0	0	Absent					
69.4	1	1	Very Low	0	0	Absent					
69.5	0	1	Very Low	0	0	Absent					
69.6	0	1	Very Low	0	1	Very low, low, medium					
69.7	1	3	Medium	1	2	High					
69.8	2	3	Medium	1	2	High					
69.9	0	2	Low	0	1	Very low, low, medium	2	0	2	5	Very low
70.0	0	0	Absent	0	0	Absent	2	1	3	6	Very low
70.1	0	0	Absent	0	0	Absent	1	0	1	15	Medium
70.2	0	0	Absent	0	0	Absent	10	1	11	13	Medium
70.3	0	2	Low	0	0	Absent	1	0	1	15	Medium
70.4	2	3	Medium	0	1	Very low, low, medium	1	2	3	7	Low
70.5	1	4	High	1	1	Very low, low, medium	2	1	3	8	Low
70.6	1	2	Low	0	1	Very low, low, medium	0	2	2	6	Very low
70.7	0	2	Low	0	1	Very low, low, medium	1	0	1	11	Medium

70.8	1	2	Low	1	1	Very low, low, medium	5	3	8	10	Low
70.9	1	6	Very high	0	2	High	0	1	1	17	High
71.0	4	7	Very high	1	2	High	4	4	8	18	High
71.1	2	7	Very high	1	2	High	7	2	9	19	High
71.2	1	5	High	0	1	Very low, low, medium	0	2	2	24	High
71.3	2	3	Medium	0	0	Absent	11	2	13	17	High
71.4	0	2	Low	0	0	Absent	2	0	2	16	High
71.5	0	1	Very Low	0	0	Absent	1	0	1	5	Very low
71.6	1	1	Very Low	0	0	Absent	1	1	2	3	Very low
71.7	0	1	Very Low	0	0	Absent	0	0	0	2	Very low
71.8	0	0	Absent	0	0	Absent	0	0	0	0	Absent
71.9	0	0	Absent	0	0	Absent	0	0	0	1	Very low
72.0	0	0	Absent	0	0	Absent	0	1	1	2	Very low
72.1	0	1	Very Low	0	1	Very low, low, medium	1	0	1	4	Very low
72.2	1	2	Low	1	1	Very low, low, medium	1	1	2	9	Low
72.3	1	3	Medium	0	1	Very low, low, medium	5	1	6	10	Low
72.4	1	2	Low	0	0	Absent	0	2	2	10	Low
72.5	0	1	Very Low	0	0	Absent	2	0	2	4	Very low
72.6	0	0	Absent	0	0	Absent	0	0	0	2	Very low
72.7	0	0	Absent	0	0	Absent	0	0	0	1	Very low
72.8	0	0	Absent	0	0	Absent	1	0	1	3	Very low
72.9	0	0	Absent	0	0	Absent	2	0	2	3	Very low
73.0	0	0	Absent	0	0	Absent	0	0	0	4	Very low
73.1	0	0	Absent	0	0	Absent	1	1	2	9	Low
73.2	0	0	Absent	0	0	Absent	7	0	7	10	Low
73.3	0	3	Medium	0	0	Absent	1	0	1	11	Medium

73.4	3	3	Medium	0	0	Absent	0	3	3	5	Very low
73.5	0	3	Medium	0	0	Absent	1	0	1	4	Very low
73.6	0	0	Absent	0	0	Absent	0	0	0	1	Very low
73.7	0	1	Very Low	0	0	Absent	0	0	0	4	Very low
73.8	1	2	Low	0	0	Absent	2	2	4	5	Very low
73.9	1	3	Medium	0	0	Absent	0	1	1	7	Low
74.0	1	4	High	0	1	Very low, low, medium	1	1	2	6	Very low
74.1	2	3	Medium	1	1	Very low, low, medium	0	3	3	7	Low
74.2	0	2	Low	0	1	Very low, low, medium	1	1	2	6	Very low
74.3	0	1	Very Low	0	0	Absent	1	0	1	4	Very low
74.4	1	2	Low	0	0	Absent	0	1	1	6	Very low
74.5	1	6	Very high	0	3	Very high	3	1	4	9	Low
74.6	4	5	High	3	3	Very high	0	4	4	8	Low
74.7	0	5	High	0	3	Very high	0	0	0	6	Very low
74.8	1	1	Very Low	0	0	Absent	1	1	2	2	Very low
74.9	0	2	Low	0	1	Very low, low, medium	0	0	0	3	Very low
75.0	1	2	Low	1	1	Very low, low, medium	0	1	1	2	Very low
75.1	1	2	Low	0	1	Very low, low, medium	0	1	1	2	Very low
75.2	0	1	Very Low	0	0	Absent	0	0	0	2	Very low
75.3	0	0	Absent	0	0	Absent	1	0	1	1	Very low
75.4	0	0	Absent	0	0	Absent	0	0	0	2	Very low
75.5	0	0	Absent	0	0	Absent	1	0	1	1	Very low
75.6	0	0	Absent	0	0	Absent	0	0	0	1	Very low
75.7	0	0	Absent	0	0	Absent	0	0	0	0	Absent
75.8	0	1	Very Low	0	1	Very low, low, medium					
75.9	1	1	Very Low	1	1	Very low, low, medium					

76.0	0	1	Very Low	0	1	Very low, low, medium					
76.1	0	0	Absent	0	0	Absent					
76.2	0	0	Absent	0	0	Absent					
76.3	0	1	Very Low	0	0	Absent					
76.4	1	3	Medium	0	0	Absent					
76.5	2	4	High	0	0	Absent					
76.6	1	3	Medium	0	0	Absent					
76.7	0	1	Very Low	0	0	Absent					
76.8	0	2	Low	0	0	Absent					
76.9	2	2	Low	0	0	Absent					
77.0	0	3	Medium	0	0	Absent					
77.1	1	1	Very Low	0	0	Absent					
77.2	0	1	Very Low	0	0	Absent					
77.3	0	0	Absent	0	0	Absent					
77.4	0	1	Very Low	0	0	Absent					
77.5	1	1	Very Low	0	0	Absent					
77.6	0	1	Very Low	0	0	Absent					
77.7	0	0	Absent	0	0	Absent					
77.8	0	1	Very Low	0	0	Absent					
77.9	1	2	Low	0	0	Absent					
78.0	1	2	Low	0	0	Absent					
78.1	0	2	Low	0	0	Absent					
78.2	1	1	Very Low	0	0	Absent					
78.3	0	1	Very Low	0	0	Absent					
78.4	0	3	Medium	0	0	Absent					
78.5	3	3	Medium	0	0	Absent					

78.6	0	4	High	0	0	Absent					
78.7	1	1	Very Low	0	0	Absent					
78.8	0	2	Low	0	0	Absent					
78.9	1	2	Low	0	0	Absent					
79.0	1	3	Medium	0	1	Very low, low, medium					
79.1	1	2	Low	1	1	Very low, low, medium					
79.2	0	1	Very Low	0	1	Very low, low, medium					
79.3	0	2	Low	0	1	Very low, low, medium					
79.4	2	4	High	1	1	Very low, low, medium					
79.5	2	4	High	0	1	Very low, low, medium					
79.6	0	3	Medium	0	0	Absent					
79.7	1	2	Low	0	0	Absent					
79.8	1	4	High	0	2	High					
79.9	2	4	High	2	2	High					
80.0	1	3	Medium	0	2	High					
80.1	0	2	Low	0	0	Absent					
80.2	1	3	Medium	0	1	Very low, low, medium					
80.3	2	5	High	1	3	Very high					
80.4	2	4	High	2	3	Very high					
80.5	0	3	Medium	0	3	Very high					
80.6	1	1	Very Low	1	1	Very low, low, medium					
80.7	0	1	Very Low	0	1	Very low, low, medium					
80.8	0	0	Absent	0	0	Absent					
80.9	0	0	Absent	0	0	Absent					
81.0	0	1	Very Low	0	1	Very low, low, medium					
81.1	1	1	Very Low	1	1	Very low, low, medium					

81.2	0	1	Very Low	0	1	Very low, low, medium					
81.3	0	0	Absent	0	0	Absent					
81.4	0	0	Absent	0	0	Absent					
81.5	0	1	Very Low	0	1	Very low, low, medium					
81.6	1	3	Medium	1	1	Very low, low, medium					
81.7	2	3	Medium	0	1	Very low, low, medium					
81.8	0	2	Low	0	0	Absent					
81.9	0	0	Absent	0	0	Absent					
82.0	0	2	Low	0	0	Absent					
82.1	2	2	Low	0	0	Absent					
82.2	0	3	Medium	0	1	Very low, low, medium					
82.3	1	2	Low	1	1	Very low, low, medium					
82.4	1	2	Low	0	1	Very low, low, medium					
82.5	0	1	Very Low	0	0	Absent					
82.6	0	2	Low	0	2	High					
82.7	2	3	Medium	2	2	High					
82.8	1	3	Medium	0	2	High					
82.9	0	1	Very Low	0	0	Absent					
83.0	0	0	Absent	0	0	Absent					
83.1	0	2	Low	0	1	Very low, low, medium					
83.2	2	2	Low	1	1	Very low, low, medium					
83.3	0	2	Low	0	1	Very low, low, medium					
83.4	0	1	Very Low	0	1	Very low, low, medium					
83.5	1	2	Low	1	2	High					
83.6	1	3	Medium	1	2	High					
83.7	1	2	Low	0	1	Very low, low, medium					

83.8	0	2	Low	0	1	Very low, low, medium					
83.9	1	3	Medium	1	2	High					
84.0	2	4	High	1	2	High					
84.1	1	4	High	0	2	High					
84.2	1	2	Low	1	1	Very low, low, medium					
84.3	0	1	Very Low	0	1	Very low, low, medium					
84.4	0	1	Very Low	0	0	Absent					
84.5	1	1	Very Low	0	0	Absent					
84.6	0	2	Low	0	1	Very low, low, medium					
84.7	1	2	Low	1	1	Very low, low, medium					
84.8	1	4	High	0	1	Very low, low, medium					
84.9	2	4	High	0	0	Absent					
85.0	1	4	High	0	0	Absent					
85.1	1	4	High	0	0	Absent					
85.2	2	3	Medium	0	0	Absent					
85.3	0	4	High	0	1	Very low, low, medium					
85.4	2	2	Low	1	1	Very low, low, medium					
85.5	0	2	Low	0	1	Very low, low, medium					
85.6	0	0	Absent	0	0	Absent					
85.7	0	2	Low	0	0	Absent					
85.8	2	3	Medium	0	1	Very low, low, medium					
85.9	1	3	Medium	1	1	Very low, low, medium					
86.0	0	2	Low	0	1	Very low, low, medium					
86.1	1	1	Very Low	0	0	Absent					
86.2	0	2	Low	0	1	Very low, low, medium					
86.3	1	1	Very Low	1	1	Very low, low, medium					

86.4	0	1	Very Low	0	1	Very low, low, medium					
86.5	0	0	Absent	0	0	Absent					
86.6	0	0	Absent	0	0	Absent					
86.7	0	0	Absent	0	0	Absent					
86.8	0	1	Very Low	0	1	Very low, low, medium					
86.9	1	1	Very Low	1	1	Very low, low, medium					
87.0	0	2	Low	0	2	High					
87.1	1	2	Low	1	1	Very low, low, medium					
87.2	1	2	Low	0	1	Very low, low, medium					
87.3	0	1	Very Low	0	0	Absent					
87.4	0	2	Low	0	1	Very low, low, medium					
87.5	2	2	Low	1	1	Very low, low, medium					
87.6	0	2	Low	0	1	Very low, low, medium					
87.7	0	0	Absent	0	0	Absent					
87.8	0	0	Absent	0	0	Absent					
87.9	0	0	Absent	0	0	Absent					
88.0	0	0	Absent	0	0	Absent					
88.1	0	0	Absent	0	0	Absent					
88.2	0	0	Absent	0	0	Absent					
88.3	0	0	Absent	0	0	Absent					
88.4	0	1	Very Low	0	0	Absent					
88.5	1	1	Very Low	0	0	Absent					
88.6	0	1	Very Low	0	0	Absent					
88.7	0	0	Absent	0	0	Absent					
88.8	0	0	Absent	0	0	Absent					
88.9	0	1	Very Low	0	1	Very low, low, medium					

89.0	1	1	Very Low	1	1	Very low, low, medium					
89.1	0	1	Very Low	0	1	Very low, low, medium					
89.2	0	0	Absent	0	0	Absent					
89.3	0	0	Absent	0	0	Absent					
89.4	0	0	Absent	0	0	Absent					
89.5	0	2	Low	0	0	Absent					
89.6	2	3	Medium	0	0	Absent					
89.7	1	3	Medium	0	0	Absent					
89.8	0	1	Very Low	0	0	Absent					
89.9	0	1	Very Low	0	1	Very low, low, medium					
90.0	1	1	Very Low	1	1	Very low, low, medium					
90.1	0	1	Very Low	0	1	Very low, low, medium					
90.2	0	1	Very Low	0	1	Very low, low, medium					
90.3	1	2	Low	1	1	Very low, low, medium					
90.4	1	2	Low	0	1	Very low, low, medium					
90.5	0	1	Very Low	0	0	Absent					
90.6	0	1	Very Low	0	0	Absent					
90.7	1	1	Very Low	0	0	Absent					
90.8	0	1	Very Low	0	0	Absent					
90.9	0	1	Very Low	0	1	Very low, low, medium					
91.0	1	1	Very Low	1	1	Very low, low, medium					
91.1	0	1	Very Low	0	1	Very low, low, medium	0	0	0	0	Absent
91.2	0	0	Absent	0	0	Absent	0	0	0	0	Absent
91.3	0	0	Absent	0	0	Absent	0	0	0	0	Absent
91.4	0	0	Absent	0	0	Absent	0	0	0	0	Absent
91.5	0	0	Absent	0	0	Absent	0	0	0	1	Very low

91.6	0	0	Absent	0	0	Absent	1	0	1	1	Very low
91.7	0	1	Very Low	0	0	Absent	0	0	0	2	Very low
91.8	1	2	Low	0	0	Absent	0	1	1	2	Very low
91.9	1	4	High	0	0	Absent	0	1	1	6	Very low
92.0	2	3	Medium	0	0	Absent	2	2	4	6	Very low
92.1	0	4	High	0	0	Absent	1	0	1	7	Low
92.2	2	5	High	0	1	Very low, low, medium	0	2	2	9	Low
92.3	3	5	High	1	1	Very low, low, medium	3	3	6	8	Low
92.4	0	4	High	0	2	High	0	0	0	9	Low
92.5	1	4	High	1	1	Very low, low, medium	2	1	3	8	Low
92.6	3	5	High	0	1	Very low, low, medium	2	3	5	14	Medium
92.7	1	7	Very high	0	0	Absent	3	3	6	16	High
92.8	3	5	High	0	0	Absent	2	3	5	17	High

APPENDIX C: BANFF CLUSTER CATEGORIES, MITIGATION ZONES AND CLUSTERS

See appendix B for description. Note: There were no 33 year road mortality clusters, 10 year mortality clusters, or wildlife observation clusters within the Banff study area section, so there is no shading.

	33 Year Mortality Clusters			10 Year Mortality Clusters			Wildlife Observation Clusters in Mitigation Zones				
Road unit	Mortality observations	Wildlife road mortality values	Cluster category	Mortality observations	Wildlife road mortality values	Cluster category	Incidental observations	Mortality observations	Total incidental and mortality	Wildlife observation values	Cluster category
0.0	0	0	Absent	0	0	Absent					
0.1	0	1	Very low	0	1	Very low, low, medium					
0.2	1	1	Very low	1	1	Very low, low, medium					
0.3	0	2	Low	0	1	Very low, low, medium					
0.4	1	1	Very low	0	0	Absent					
0.5	0	1	Very low	0	0	Absent					
0.6	0	0	Absent	0	0	Absent					
0.7	0	0	Absent	0	0	Absent					
0.8	0	4	High	0	0	Absent					
0.9	4	4	High	0	0	Absent					
1.0	0	4	High	0	0	Absent					
1.1	0	0	Absent	0	0	Absent					
1.2	0	0	Absent	0	0	Absent					
1.3	0	0	Absent	0	0	Absent					
1.4	0	0	Absent	0	0	Absent					

1.5	0	0	Absent	0	0	Absent					
1.6	0	1	Very low	0	0	Absent					
1.7	1	1	Very low	0	0	Absent					
1.8	0	1	Very low	0	0	Absent					
1.9	0	0	Absent	0	0	Absent					
2.0	0	0	Absent	0	0	Absent					
2.1	0	0	Absent	0	0	Absent					
2.2	0	0	Absent	0	0	Absent					
2.3	0	0	Absent	0	0	Absent					
2.4	0	0	Absent	0	0	Absent					
2.5	0	1	Very low	0	1	Very low, low, medium					
2.6	1	1	Very low	1	1	Very low, low, medium					
2.7	0	1	Very low	0	1	Very low, low, medium					
2.8	0	0	Absent	0	0	Absent					
2.9	0	0	Absent	0	0	Absent					
3.0	0	0	Absent	0	0	Absent					
3.1	0	0	Absent	0	0	Absent					
3.2	0	0	Absent	0	0	Absent					
3.3	0	0	Absent	0	0	Absent					
3.4	0	0	Absent	0	0	Absent					
3.5	0	0	Absent	0	0	Absent					
3.6	0	0	Absent	0	0	Absent					
3.7	0	0	Absent	0	0	Absent					
3.8	0	0	Absent	0	0	Absent					
3.9	0	0	Absent	0	0	Absent					
4.0	0	0	Absent	0	0	Absent					

4.1	0	0	Absent	0	0	Absent					
4.2	0	0	Absent	0	0	Absent					
4.3	0	0	Absent	0	0	Absent					
4.4	0	0	Absent	0	0	Absent					
4.5	0	0	Absent	0	0	Absent					
4.6	0	0	Absent	0	0	Absent					
4.7	0	1	Very low	0	0	Absent					
4.8	1	1	Very low	0	0	Absent					
4.9	0	1	Very low	0	0	Absent					
5.0	0	1	Very low	0	1	Very low, low, medium					
5.1	1	1	Very low	1	1	Very low, low, medium					
5.2	0	2	Low	0	2	High					
5.3	1	1	Very low	1	1	Very low, low, medium					
5.4	0	1	Very low	0	1	Very low, low, medium					
5.5	0	0	Absent	0	0	Absent					
5.6	0	0	Absent	0	0	Absent					
5.7	0	0	Absent	0	0	Absent					
5.8	0	0	Absent	0	0	Absent					
5.9	0	0	Absent	0	0	Absent					
6.0	0	0	Absent	0	0	Absent					
6.1	0	0	Absent	0	0	Absent					
6.2	0	0	Absent	0	0	Absent					
6.3	0	0	Absent	0	0	Absent					
6.4	0	0	Absent	0	0	Absent					
6.5	0	0	Absent	0	0	Absent					
6.6	0	0	Absent	0	0	Absent					

6.7	0	0	Absent	0	0	Absent					
6.8	0	0	Absent	0	0	Absent					
6.9	0	0	Absent	0	0	Absent					
7.0	0	0	Absent	0	0	Absent					
7.1	0	0	Absent	0	0	Absent					
7.2	0	0	Absent	0	0	Absent					
7.3	0	0	Absent	0	0	Absent					
7.4	0	0	Absent	0	0	Absent					
7.5	0	0	Absent	0	0	Absent					
7.6	0	0	Absent	0	0	Absent					
7.7	0	1	Very low	0	1	Very low, low, medium					
7.8	1	1	Very low	1	1	Very low, low, medium					
7.9	0	2	Low	0	2	High					
8.0	1	1	Very low	1	1	Very low, low, medium					
8.1	0	1	Very low	0	1	Very low, low, medium					
8.2	0	0	Absent	0	0	Absent					
8.3	0	2	Low	0	2	High					
8.4	2	2	Low	1	2	High					
8.5	0	2	Low	0	2	High					
8.6	0	0	Absent	0	0	Absent					
8.7	0	0	Absent	0	0	Absent					
8.8	0	0	Absent	0	0	Absent					
8.9	0	0	Absent	0	0	Absent	0	0	0	0	Absent
9.0	0	0	Absent	0	0	Absent	0	0	0	0	Absent
9.1	0	1	Very low	0	0	Absent	0	0	0	1	Very low
9.2	1	1	Very low	0	0	Absent	0	1	1	1	Very low

9.3	0	1	Very low	0	0	Absent	0	0	0	2	Very low
9.4	0	1	Very low	0	0	Absent	1	0	1	2	Very low
9.5	1	1	Very low	0	0	Absent	0	1	1	2	Very low
9.6	0	2	Low	0	0	Absent	0	0	0	5	Very low
9.7	1	1	Very low	0	0	Absent	3	1	4	6	Very low
9.8	0	2	Low	0	0	Absent	1	1	2	12	Medium
9.9	1	4	High	0	0	Absent	5	1	6	13	Medium

APPENDIX D: RADIUM HOT SPRINGS CLUSTER CATEGORIES, MITIGATION ZONES AND CLUSTERS

See appendix B for description.

	33 Year Mortality Clusters			10 Year Mortality Clusters			Wildlife Observation Clusters in Mitigation Zones				
Road unit	Mortality observations	Bighorn sheep road mortality values	Cluster category	Mortality observations	Bighorn sheep road mortality values	Cluster category	Incidental observations	Mortality observations	Total incidental and mortality	Bighorn sheep observation values	Cluster category
Radium North											
0	1	2	Low	0	0	Absent					
0.1	0	2	Low	0	1	Very low, low	0	0	0	0	Absent
0.2	1	4	High	1	3	Medium	0	1	1	3	Low
0.3	3	9	Very high	2	8	Very high	0	2	2	8	High
0.4	5	9	Very high	5	8	Very high	0	5	5	8	High
0.5	1	6	Very high	1	6	High	0	1	1	6	Medium
0.6	0	2	Low	0	2	Medium	0	0	0	1	Very low
0.7	1	1	Very low	1	1	Very low, low					
0.8	0	1	Very low	0	1	Very low, low					
0.9	0	0	Absent	0	0	Absent					
1	0	0	Absent	0	0	Absent					
1.1	0	0	Absent	0	0	Absent					
1.2	0	0	Absent	0	0	Absent					
1.3	0	0	Absent	0	0	Absent					
1.4	0	1	Very low	0	1	Very low, low					

1.5	1	1	Very low	1	1	Very low, low				
1.6	0	1	Very low	0	1	Very low, low				
1.7	0	0	Absent	0	0	Absent				
1.8	0	0	Absent	0	0	Absent				
1.9	0	0	Absent	0	0	Absent				
2	0	0	Absent	0	0	Absent				
2.1	0	0	Absent	0	0	Absent				
2.2	0	0	Absent	0	0	Absent				
2.3	0	0	Absent	0	0	Absent				
2.4	0	0	Absent	0	0	Absent				
2.5	0	0	Absent	0	0	Absent				
2.6	0	0	Absent	0	0	Absent				
2.7	0	0	Absent	0	0	Absent				
2.8	0	0	Absent	0	0	Absent				
2.9	0	0	Absent	0	0	Absent				
3	0	0	Absent	0	0	Absent				
3.1	0	0	Absent	0	0	Absent				
3.2	0	0	Absent	0	0	Absent				
3.3	0	0	Absent	0	0	Absent				
3.4	0	0	Absent	0	0	Absent				
3.5	0	0	Absent	0	0	Absent				
3.6	0	0	Absent	0	0	Absent				
3.7	0	0	Absent	0	0	Absent				
3.8	0	0	Absent	0	0	Absent				
3.9	0	0	Absent	0	0	Absent				
Radium South										

0	1	2	Low	0	0	Absent					
0.1	0	1	Very low	0	0	Absent					
0.2	0	1	Very low	0	1	Very low, low					
0.3	1	2	Low	1	2	Medium					
0.4	1	2	Low	1	2	Medium					
0.5	0	2	Low	0	2	Medium					
0.6	1	4	High	1	3	Medium	1	1	2	4	Low
0.7	3	5	High	2	4	High	0	2	2	5	Low
0.8	1	4	High	1	3	Medium	0	1	1	3	Low
0.9	0	1	Very low	0	1	Very low, low	0	0	0	1	Very low
1.0	0	0	Absent	0	0	Absent	0	0	0	0	Absent
1.1	0	3	Medium	0	3	Medium	0	0	0	4	Low
1.2	3	6	Very high	3	6	High	1	3	4	8	High
1.3	3	7	Very high	3	7	High	1	3	4	9	High
1.4	1	7	Very high	1	7	High	0	1	1	8	High
1.5	3	10	Very high	3	10	Very high	0	3	3	10	Very high
1.6	6	18	Very high	6	18	Very high	0	6	6	18	Very high
1.7	9	17	Very high	9	17	Very high	0	9	9	17	Very high
1.8	2	15	Very high	2	15	Very high	0	2	2	16	Very high
1.9	4	11	Very high	4	11	Very high	1	4	5	12	Very high
2.0	5	10	Very high	5	10	Very high	0	6	6	12	Very high
2.1	1	10	Very high	1	9	Very high	0	1	1	10	Very high
2.2	4	6	Very high	3	5	High	0	3	3	5	Medium
2.3	1	6	Very high	1	5	High	0	1	1	5	Medium
2.4	1	2	Low	1	2	Medium	0	1	1	2	Low
2.5	0	1	Very low	0	1	Very low, low	0	0	0	1	Very low

2.6	0	1	Very low	0	1	Very low, low	0	0	0	1	Very low
2.7	1	1	Very low	1	1	Very low, low	0	1	1	1	Very low
2.8	0	1	Very low	0	1	Very low, low	0	0	0	1	Very low
2.9	0	0	Absent	0	0	Absent	0	0	0	0	Absent
3.0	0	0	Absent	0	0	Absent	0	0	0	0	Absent
3.1	0	0	Absent	0	0	Absent	0	0	0	0	Absent
3.2	0	0	Absent	0	0	Absent	0	0	0	0	Absent
3.3	0	0	Absent	0	0	Absent	0	0	0	0	Absent
3.4	0	0	Absent	0	0	Absent					
3.5	0	0	Absent	0	0	Absent					
3.6	0	0	Absent	0	0	Absent					
3.7	0	0	Absent	0	0	Absent					
3.8	0	0	Absent	0	0	Absent					
3.9	0	0	Absent	0	0	Absent					
Radium East											
0	0	2	Low	0	0	Absent					
0.1	0	1	Very Low	0	1	Very low, low					
0.2	1	2	Low	1	1	Very low, low					
0.3	1	3	Medium	0	1	Very low, low					
0.4	1	2	Low	0	0	Absent					
0.5	0	1	Very Low	0	0	Absent					
0.6	0	0	Absent	0	0	Absent					
0.7	0	2	Low	0	0	Absent					
0.8	2	3	Medium	0	0	Absent					
0.9	1	4	High	0	0	Absent					
1.0	1	4	High	0	0	Absent					

APPENDIX E: PERCENTAGE PER SPECIES OF ROAD MORTALITIES IN 33 YEAR MORTALITY CLUSTERS IN KOOTENAY/BANFF

Observations of road mortalities by species within 33 year mortality clusters in Kootenay and Banff National Park. The data relate to the focal species for road mortality observations (Table 2) and are based on the 33 year data set within 100m of the highway.

Begin and end point 33 year mortality cluster (km*)	Species	Percentage
1.6 – 2.1	Elk	50.00
	Mule deer	25.00
	White tailed deer	25.00
2.3 - 3.5	Bighorn sheep	75.00
	Mule deer	10.00
	Black bear	5.00
	Deer	5.00
	Elk	5.00
4.0 – 4.7	Mule deer	66.67
	Deer	8.33
	Elk	8.33
	Moose	8.33
	Bighorn sheep	8.33
5.0 – 5.2	Mule deer	85.71
	Bighorn sheep	14.29
6.8 – 7.3	Mule deer	57.89
	Bighorn sheep	31.58
	Black bear	5.26
	White tailed deer	5.26
8.3 – 8.9	Mule deer	50.00

	Elk	28.57
	Coyote	7.14
	Bighorn sheep	7.14
	White tailed deer	7.14
10.5 – 10.8	Mule deer	50.00
	Deer	25.00
	Bighorn sheep	25.00
11.8 – 12.2	Black bear	50.00
	Elk	37.50
	White tailed deer	12.50
14.6 – 15.0	Elk	37.50
	Mule deer	37.50
	Coyote	12.50
	White tailed deer	12.50
18.3 – 18.8	Elk	45.45
	White tailed deer	36.36
	Black bear	9.09
	Coyote	9.09
20.5 – 20.9	White tailed deer	66.67
	Black bear	16.67
	Elk	16.67
21.3 – 21.6	White tailed deer	50.00
	Black bear	16.67
	Elk	16.67
	Mule deer	16.67
23.0 – 23.5	White tailed deer	57.14

	Elk	28.57
	Deer	7.14
	Mule deer	7.14
25.5 – 26.9	White tailed deer	40.00
	Elk	36.00
	Black bear	8.00
	Deer	6.00
	Coyote	6.00
	Mule deer	4.00
27.1 – 27.8	White tailed deer	50.00
	Elk	43.75
	Mule deer	6.25
31.4 – 31.7	Elk	62.50
	Mule deer	12.50
	White tailed deer	12.50
	Coyote	12.50
36.7 - 37.8	White tailed deer	71.28
	Elk	14.89
	Mule deer	4.26
	Coyote	3.72
	Deer	2.13
	Moose	2.13
	Wolf	1.60
38.7 – 39.5	White tailed deer	100.00
39.9 – 42.7	White tailed deer	72.81
	Elk	11.40

	Mule deer	7.02
	Moose	2.63
	Black bear	1.75
	Coyote	1.75
	Deer	1.75
	Wolf	0.88
43.3 – 43.7	Elk	41.67
	White tailed deer	41.67
	Coyote	8.33
	Moose	8.33
44.1 – 44.3	White tailed deer	60.00
	Coyote	20.00
	Moose	20.00
44.8 – 45.5	White tailed deer	46.15
	Elk	38.46
	Black bear	7.69
	Wolf	7.69
45.6 - 46.6	White tailed deer	45.83
	Elk	33.33
	Deer	12.50
	Mule deer	4.17
	Wolf	4.17
47.0 – 47.2	Elk	66.67
	Coyote	16.67
	Deer	16.67
53.1 – 53.5	Moose	50.00

	Coyote	25.00
	White tailed deer	12.50
	Wolf	12.50
55.2 – 55.6	White tailed deer	62.50
	Moose	25.00
	Black bear	12.50
61.5 – 61.9	Elk	33.33
	White tailed deer	33.33
	Moose	16.67
	Coyote	16.67
70.9 -71.3	Elk	62.50
	Deer	12.50
	White tailed deer	12.50
	Coyote	12.50
74.5 – 74.8	White tailed deer	80.00
	Moose	20.00
92.1 – 9.9	Elk	42.86
	White tailed deer	21.43
	Moose	21.43
	Deer	7.14
	Mule deer	7.14

* = the start and end points are actual points rather than 100 m road units.

APPENDIX F: PERCENTAGE PER SPECIES OF MORTALITIES IN 10 YEAR MORTALITY CLUSTERS IN KOOTENAY/BANFF

Observations of road mortalities by species within 10 year mortality clusters in Kootenay and Banff National Park. The data relate to the focal species for road mortality observations (Table 2) and are based on the 10 year data set within 100m of the highway. This does not include 10 year mortality clusters not contained within mitigation zones.

Begin and end point 10 year mortality cluster (km*)	Species	Percentage
8.5 – 9.0	Elk	50.00
	Mule deer	25.00
	White tailed deer	25.00
10.0 – 10.4	Mule deer	66.67
	Bighorn sheep	33.33
14.9 – 15.2	Coyote	100.00
15.3 – 15.9	Mule deer	50.00
	White tailed deer	50.00
16.0 – 16.4	White tailed deer	100.00
18.5 – 18.8	White tailed deer	66.67
	Coyote	33.33
19.9 – 20.9	White tailed deer	55.56
	Black bear	22.22
	Elk	11.11
	Mule deer	11.11
21.3 – 21.6	White tailed deer	100.00
23.0 – 23.4	White tailed deer	80.00
	Mule deer	20.00
25.6 – 25.9	Elk	66.67
	White tailed deer	33.33
26.3 – 26.8	White tailed deer	77.78

	Deer	22.22
27.1 – 27.5	White tailed deer	60.00
	Elk	40.00
28.4 - 29.0	White tailed deer	80.00
	Mule deer	20.00
30.9 – 31.2	White tailed deer	100.00
32.4 – 36.6	White tailed deer	82.69
	Deer	5.77
	Coyote	3.85
	Elk	3.85
	Mule deer	1.92
	Wolf	1.92
36.7 - 37.8	White tailed deer	100.00
38.7 – 39.6	White tailed deer	100.00
40.0 – 42.6	White tailed deer	82.93
	Mule deer	7.32
	Coyote	2.44
	Deer	2.44
	Moose	2.44
	Wolf	2.44
44.1 – 44.4	White tailed deer	66.67
	Moose	33.33
44.6 – 45.1	White tailed deer	80.00
	Black bear	20.00
45.2 – 45.5	White tailed deer	100.00
45.6 - 46.4	White tailed deer	71.43

	Deer	14.29
	Elk	14.29
53.0 – 53.6	Moose	66.67
	Coyote	16.67
	White tailed deer	16.67
54.1 – 54.7	Moose	60.00
	Coyote	20.00
	Mule deer	20.00
55.2 – 55.7	White tailed deer	80.00
	Moose	20.00
74.5 – 74.8	White tailed deer	66.67
	Moose	33.33

* = the start and end points are actual points rather than 100 m road units.

APPENDIX G: NUMBER AND PERCENTAGE PER SPECIES OF WILDLIFE OBSERVATIONS WITHIN MITIGATION ZONES IN KOOTENAY/BANFF

Species observed in the mitigation zones in Kootenay and Banff National Park, based on observation data for all species, dead or alive, within 100m of the highway over 33 years.

Begin and end point mitigation zones (km*)	Species	Number of observations	Percentage
2.0 - 48.3	White-tailed deer	1033	33.47
	Black bear	613	19.86
	Elk	548	17.76
	Bighorn sheep	214	6.93
	Mule deer	156	5.06
	Coyote	123	3.99
	Wolf	101	3.27
	Moose	94	3.05
	Mountain goat	56	1.81
	Deer	33	1.07
	Bird	24	0.78
	Small rodent	19	0.62
	Marten	14	0.45
	Herpetofauna	11	0.36
	Porcupine	9	0.29
	Snowshoe hare	7	0.23
	Grizzly bear	6	0.19
	Skunk	6	0.19
	Bear	4	0.13
	Cougar	4	0.13
	Beaver	3	0.10

	Hoary marmot	2	0.06
	Unknown	2	0.06
	Badger	1	0.03
	Bobcat	1	0.03
	Red fox	1	0.03
	Wolverine	1	0.03
52.1 – 56.6	Elk	47	31.97
	Moose	37	25.17
	Black bear	17	11.56
	White-tailed deer	15	10.20
	Mule deer	11	7.48
	Coyote	6	4.08
	Wolf	6	4.08
	Canada lynx	2	1.36
	Small rodent	2	1.36
	Bear	1	0.68
	Bird	1	0.68
	Grizzly bear	1	0.68
	Porcupine	1	0.68
60.5 – 62.9	Black bear	16	26.67
	Elk	12	20.00
	Moose	10	16.67
	White-tailed deer	8	13.33
	Coyote	4	6.67
	Pine marten	4	6.67
	Grizzly bear	2	3.33

	Bear	1	1.67
	Deer	1	1.67
	Mule deer	1	1.67
	Wolf	1	1.67
69.9 – 75.8	Elk	49	37.12
	Black bear	19	14.39
	White-tailed deer	18	13.64
	Moose	12	9.09
	Porcupine	6	4.55
	Coyote	5	3.79
	Snowshoe hare	5	3.79
	Mule deer	4	3.03
	Small rodent	4	3.03
	Wolf	4	3.03
	Deer	2	1.52
	Grizzly bear	2	1.52
	Pine marten	2	1.52
91.1 – 8.9 (in Banff section)	Elk	13	26.00
	Moose	7	14.00
	Bighorn sheep	7	14.00
	Black bear	3	6.00
	White-tailed deer	3	6.00
	Wolf	3	6.00
	Mountain goat	2	4.00
	Mule deer	2	4.00
	Snowshoe hare	2	4.00

	Wolverine	2	4.00
	Badger	1	2.00
	Bear	1	2.00
	Cougar	1	2.00
	Deer	1	2.00
	Hoary marmot	1	2.00
	Canada lynx	1	2.00

* = the start and end points are actual points rather than 100 m road units.

APPENDIX H: NUMBER AND PERCENTAGE PER SPECIES OF WILDLIFE OBSERVATIONS WITHIN WILDLIFE OBSERVATION CLUSTERS IN KOOTENAY/BANFF

Species observed in the wildlife observation clusters within mitigation zones in Kootenay and Banff National Park, based on observation data for all species, dead or alive, within 100m of the highway over 33 years.

Begin and end point wildlife observation cluster (km*)	Species	Number of observations
2.0 – 2.2	Bighorn sheep	23
	Small rodents	2
	Mule deer	1
	Herpetofauna	1
2.3 – 3.3	Bighorn sheep	109
	Black bear	5
	Mule deer	4
	Coyote	1
	Deer	1
	Mountain goat	1
3.6 – 4.2	Black bear	15
	Bighorn sheep	11
	Mule deer	7
	Herpetofauna	3
	Bird	1
	Coyote	1
	Deer	1
	Elk	1
	Mountain goat	1
7.0 – 7.3	Mule deer	11
	Bighorn sheep	9

	Black bear	8
	Coyote	1
	Moose	1
	White tailed deer	1
	Wolf	1
8.0 – 9.0	Black bear	39
	Mule deer	9
	Elk	5
	Coyote	3
	Bighorn sheep	2
	White tailed deer	2
	Bear	1
	Bird	1
	Bobcat	1
	Cougar	1
	Deer	1
	Moose	1
	Wolf	1
10.6 - 11.0	Black bear	19
	Bighorn sheep	10
	Mule Deer	2
	Coyote	1
	Deer	1
	Elk	1
	Marten	1
	Wolf	1

11.3 - 12.2	Black bear	77
	Elk	10
	Coyote	4
	Mule deer	3
	Deer	1
	Moose	1
	Porcupine	1
	White tailed deer	1
14.5 - 15.2	Black bear	32
	Mule deer	9
	Elk	6
	Coyote	5
	Moose	5
	Bighorn sheep	2
	Snowshoe hare	2
	White tailed Deer	2
17.8 – 19.0	Black bear	45
	White tailed Deer	28
	Elk	20
	Moose	15
	Coyote	4
	Bird	2
	Mule deer	1
	Snowshoe hare	1
19.2 – 19.6	Moose	10
	White tailed Deer	8

	Elk	7
	Black bear	5
	Mule deer	2
	Bird	1
	Coyote	1
	Marten	1
	Wolf	1
19.8 - 20.3	Elk	13
	White tailed Deer	11
	Moose	10
	Mule deer	5
	Black bear	2
	Coyote	2
21.3 - 21.7	White tailed Deer	11
	Moose	7
	Elk	4
	Black bear	3
	Coyote	2
	Mule deer	2
	Wolf	2
23.0 - 23.5	Elk	26
	White tailed Deer	21
	Black bear	6
	Mule deer	3
	Coyote	2
	Deer	2

23.9 - 24.3	Elk	18
	White tailed Deer	5
	Bird	1
	Deer	1
	Mule deer	1
26.1 – 27.6	White tailed Deer	78
	Elk	64
	Black bear	22
	Mule deer	9
	Coyote	6
	Wolf	5
	Deer	3
	Bird	1
	Moose	1
32.1 – 36.0	White tailed Deer	267
	Elk	103
	Black bear	47
	Wolf	15
	Coyote	14
	Mule deer	6
	Moose	5
	Deer	4
	Beaver	3
	Marten	3
	Bird	2
	Grizzly bear	2

	Small rodents	1
	Porcupine	1
	Red fox	1
	Skunk	1
36.1- 37.7	White tailed Deer	108
	Elk	19
	Black bear	17
	Wolf	7
	Mule deer	4
	Coyote	3
	Moose	3
	Cougar	1
	Deer	1
	Grizzly bear	1
	Porcupine	1
	Wolverine	1
38.1 – 38.4	White tailed Deer	18
	Black bear	6
	Elk	5
	Wolf	1
38.9 – 39.4	White tailed Deer	22
	Elk	8
	Black bear	3
	Wolf	2
39.9 – 41.4	White tailed Deer	92
	Elk	21

	Black bear	17
	Mule deer	9
	Wolf	5
	Coyote	4
	Bird	3
	Deer	3
	Moose	3
41.5 – 42.7	White tailed Deer	54
	Black bear	28
	Elk	26
	Wolf	12
	Coyote	5
	Moose	4
	Small rodent	3
	Bird	2
	Mule deer	2
	Marten	1
	Skunk	1
43.0 – 43.7	White tailed Deer	27
	Elk	18
	Small rodent	7
	Herpetofauna	6
	Coyote	5
	Black bear	4
	Bird	3
	Wolf	3

	Moose	2
	Deer	1
	Grizzly bear	1
	Skunk	1
45.0 - 45.9	White tailed Deer	21
	Elk	17
	Black bear	6
	Wolf	5
	Coyote	4
	Marten	3
	Grizzly bear	2
	Deer	1
	Bird	1
46.1 - 46.4	Elk	16
	White tailed Deer	5
	Black bear	3
	Deer	2
	Wolf	2
	Badger	1
	Coyote	1
	Mountain goat	1
	Mule deer	1
	Bird	1
47.0 - 47.7	Mountain goat	44
	Elk	18
	Bighorn sheep	6

	Wolf	6
	Black bear	2
	Coyote	2
	Deer	2
	Moose	2
	Small rodent	1
	Mule deer	1

* = the start and end points are actual points rather than 100 m road units.

APPENDIX I: SUPPLEMENTAL WILDLIFE OBSERVATIONS WITHIN MITIGATION ZONES

Wildlife observations (alive, tracks) within the mitigation zones in Kootenay and Banff National Park. The data were based on: interviews with Alan Dibb and Drew Sinclair of Kootenay National Park, Parks Canada; spatial data (UTMS) locations of wildlife tracks in snow on specific transects within Kootenay Valley (Spiteri 2007); and spatial data (UTMS) locations of wolf tracks in snow crossing Highway 93 in Kootenay National Park (Olsson 2002).

Mitigation Zone	Start and end point (km*)	Species	Source
2.0 - 48.3	2.0 – 3.9	Cougar habitat	Drew Sinclair
	4.0 – 8.3	Mule deer crossing	Drew Sinclair
	7.1 – 9.7	Sensitive species movement area, especially grizzly bears	Alan Dibb
	8.3 – 11.1	Mountain goat habitat, do not cross	Drew Sinclair
	10.7 – 10.8	Mineral lick, mostly bighorn sheep at road but do not move along road. In summer.	Alan Dibb
	11.1 – 13.8	Mule deer and elk crossing	Drew Sinclair
	11.7 – 12.4	Black bears for dandelions near Olive Lake. In late May or June.	Alan Dibb
	13.3 – 13.4	One wolf track sighting	Emma Olsson
	13.3 – 13.4	Two lynx sightings	Drew Sinclair
	15.7 – 16.6	Mule deer and elk crossing	Drew Sinclair
	18.1 – 20.2	Moose crossing	Drew Sinclair
	20.1 – 20.2	One wolf track sighting	Emma Olsson
	20.4 – 20.5	One wolf track sighting	Emma Olsson
	22.5 – 23.5	Elk crossing and elk habitat	Drew Sinclair
	23.7 – 23.8	Sixteen Mile roadkill pit	Drew Sinclair
	23.8 – 24.0	Four wolf track sightings	Emma Olsson

	23.8 – 24.9	White tailed deer crossing	Drew Sinclair
	24.4 – 24.6	Three wolf track sightings	Emma Olsson
	24.7 – 24.9	Two wolf track sightings	Emma Olsson
	24.9 – 29.5	White tailed deer and elk crossing	Drew Sinclair
	25.1 – 25.3	Four wolf track sightings	Emma Olsson
	25.7 – 25.8	One wolf track sighting	Emma Olsson
	26.0 – 26.1	Elk habitat	Drew Sinclair
	26.5 – 26.7	Four wolf track sightings	Emma Olsson
	26.6 – 26.7	Bobcat, deer, and wolf tracks sightings	Arian Spiteri
	26.8 – 26.9	Two wolf track sightings	Emma Olsson
	27.0 – 27.1	Two wolf track sightings	Emma Olsson
	27.3 – 27.5	Two wolf track sightings	Emma Olsson
	27.8 – 28.0	Two wolf track sightings	Emma Olsson
	28.2 – 28.4	Three wolf track sightings	Emma Olsson
	29.0 – 29.1	One wolf track sighting	Emma Olsson
	33.4 - 42.1	Frequent wolf movement, wolf den a few kilometers nearby, wolves move on fire roads. Dolly Varden Creek a funnel for animals.	Alan Dibb
	33.6 – 33.7	One wolf track sighting	Emma Olsson
	33.7 – 35.3	White tailed deer roadkills, historical elk area	Drew Sinclair
	35.1 – 35.2	Coyote, deer, and elk tracks sightings	Arian Spiteri
	35.5 – 35.8	Four wolf track sightings	Emma Olsson
	36.0 – 36.2	Two wolf track sightings	Emma Olsson

	36.9 – 37.0	Elk, deer, moose, and wolf tracks sightings	Arian Spiteri
	36.9 – 37.0	Two wolf track sightings	Emma Olsson
	37.1 – 37.2	One wolf track sighting	Emma Olsson
	37.4 – 37.5	Two wolf track sightings	Emma Olsson
	37.7 – 37.8	One wolf track sighting	Emma Olsson
	37.8 – 42.2	White tailed deer crossing	Drew Sinclair
	39.0 – 39.1	One wolf track sighting	Emma Olsson
	39.2 – 39.3	One wolf track sighting	Emma Olsson
	39.3 – 39.9	White tailed deer and elk movement on old airstrip and open area from burn 5 years ago	Alan Dibb
	40.0 – 40.1	One wolf track sighting	Emma Olsson
	40.5 – 48.3	Wolf crossing and habitat	Drew Sinclair
	41.6 – 41.7	One wolf track sighting	Emma Olsson
	42.2 – 42.3	Moose and wolf tracks sightings	Arian Spiteri
	42.3 – 45.5	West-east valley bottom wildlife movement. Wolves, black bears, white tailed deer.	Alan Dibb
	42.4 – 42.5	One wolf track sighting	Emma Olsson
	44.7 – 45.0	Multiple ponds nearby. Sora Pond was a past wolf den site.	Alan Dibb
	45.2 – 45.4	Roadkill pit	Drew Sinclair
	45.6 – 45.7	One wolf track sighting	Emma Olsson
	45.8 – 46.1	Gravel pit and secondary roadkill pit	Drew Sinclair
	47.0 – 47.2	Mountain goat mineral lick, no crossings	Drew Sinclair
52.1 – 56.6	52.1 – 52.6	Elk crossing habitat, includes winter habitat	Drew Sinclair

	52.6 – 55.7	Moose crossing	Drew Sinclair
	52.9 – 53.0	One wolf track sighting	Emma Olsson
	54.8 – 54.9	Animal mineral lick	Drew Sinclair
	54.9 – 56.5	Simpson River wildlife movement area, of wolves, bears, ungulates	Alan Dibb
	55.7 – 56.6	Marten habitat	Drew Sinclair
	55.7 – 56.6	Moose crossing	Drew Sinclair
60.5 – 62.9	60.5 – 61.9	Grizzly crossing	Drew Sinclair
	60.5 – 61.9	Moose crossing	Drew Sinclair
	61.9 – 62.9	Wolf crossing, wolf habitat	Drew Sinclair
	61.9 – 62.9	Grizzly crossing	Drew Sinclair
69.9 – 75.8	69.9 – 75.8	Wolf crossing, wolf habitat	Drew Sinclair
	70.6 – 70.8	Historic wolf pack	Drew Sinclair
	74.7 – 74.8	Lynx sighting	Drew Sinclair
91.1 – 8.9 (in Banff section)	91.1 – 9.9	Grizzly crossing and habitat	Drew Sinclair

. * = the start and end points are actual points rather than 100 m road units.

APPENDIX J: SUGGESTED SAFE CROSSING OPPORTUNITIES WITHIN THE MITIGATION ZONES IN KOOTENAY AND BANFF NATIONAL PARK

For indicative dimensions see Table 22. The authors of the report encourage the users of these data to be flexible with the suggestions listed in this appendix. Furthermore, the authors of this report have provided tools for the users of this report for alternate configurations of the mitigation measures (see section 8.7)

Road unit	Safe Crossing Opportunity	Primary target species	Comments
2.5-2.6	Wildlife overpass	Bighorn sheep	This is an existing road tunnel (about 80 m long) (minimal costs). One or more wildlife bridges across the nearby Sinclair Creek may have to be provided for to accommodate species that may not be able to cross the creek otherwise at this location.
4.5-4.6	Large mammal underpass	Black bear, bighorn sheep, mule deer	This appears the “optimal point” where a valley on the west side matches up with a drainage on the east side, and it would encourage animals to keep some distance from Park Canada facilities on the west side.
7.0-7.1	Large mammal underpass	Mule deer, bighorn sheep, black bear	This location falls within a wildlife observation cluster…
8.7-8.8	Large mammal underpass	Black bear, mule deer, elk	This location falls within a wildlife observation cluster.
10.6-10.7	Large mammal underpass	Black bear, bighorn sheep, mule deer	This location falls within a wildlife observation cluster.
11.9-12.0	Large mammal underpass	Black bear, elk	Location matches up with creek coming in from west side. This location falls within a wildlife observation cluster.
15.0-15.1	Wildlife overpass	Black bear, mule deer, elk, moose, coyote	Location matches up with ridge coming in from west side and continuing on east side. Alternatively, an over span bridge may be put in around 14.9 km. This location falls within a wildlife observation cluster.
18.5-18.6	Large mammal underpass	Black bear, white-tailed deer, elk, moose,	Location matches up with creek coming in from west side, just north of Jct with Settler’s rd. This location falls within a wildlife observation cluster.
19.8-20.0	Large mammal underpass	Elk, white-tailed deer, moose, mule deer, black bear, coyote	This location falls within a wildlife observation cluster.
21.7-21.9	Large mammal underpass	White-tailed deer, moose, elk, black bear, coyote, mule deer, wolf	This location falls within a wildlife observation cluster.
23.2-23.3	Large mammal underpass	Elk, white-tailed deer, black bear, mule deer	Location matches up with creek coming in from west side. This location falls within a wildlife observation cluster.
24.1-24.2	Large mammal	Elk, white-tailed deer	This location falls within a wildlife

	underpass		observation cluster.
26.3-26.4	Large mammal underpass	White-tailed deer, elk, black bear, mule deer	This location falls within a wildlife observation cluster.
32.1-32.2	Large mammal underpass	White-tailed deer, elk, black bear, wolf, coyote, mule deer, moose, (grizzly bear)	This location falls within a wildlife observation cluster.
34.1-34.2	Large mammal underpass	White-tailed deer, elk, black bear, wolf, coyote, mule deer, moose, (grizzly bear)	This location falls within a wildlife observation cluster.
35.2-35.3	Wide and high over span bridge	White-tailed deer, elk, black bear, wolf, coyote, mule deer, moose, (grizzly bear)	Location matches up with creek coming in from west side. This location falls within a wildlife observation cluster.
36.8-36.9	Large mammal underpass	White-tailed deer, elk, black bear, wolf (grizzly bear)	This location falls within a wildlife observation cluster.
37.9-38.0	Over span bridge	White-tailed deer, elk, black bear, wolf	Location matches up with creek coming in from west side.
39.1-39.2	Large mammal underpass	White-tailed deer, elk, black bear, wolf	This location falls within a wildlife observation cluster.
40.5-40.6	Large mammal underpass	White-tailed deer, elk, black bear, mule deer, wolf	This location falls within a wildlife observation cluster.
41.7-41.8	Large mammal underpass	White-tailed deer, black bear, elk, wolf, coyote, (grizzly bear)	This location falls within a wildlife observation cluster.
42.6-42.7	Wide and high over span bridge	White-tailed deer, black bear, elk, wolf, coyote, (grizzly bear)	This is an existing bridge (Kootenay Crossing) (minimal costs). This location falls within a wildlife observation cluster.
43.0-43.1	Wildlife overpass	White-tailed deer, elk, coyote, black bear, (grizzly bear)	This location matches up with a ridge coming in from the west side and a ridge parallel to the road on the east side. This location falls within a wildlife observation cluster.
45.3-45.4	Large mammal underpass	White-tailed deer, elk, black bear, wolf, coyote, pine marten, (grizzly bear)	This location falls within a wildlife observation cluster.
46.2-46.3	Large mammal underpass	Elk, white-tailed deer, black bear, wolf, (grizzly bear)	This location falls within a wildlife observation cluster.
47.1-47.2	Large mammal underpass	Mountain goat, elk, bighorn sheep, wolf	Note: cliff on west side road and river on east side make an under or overpass difficult at the base of the cliffs. Underpass positioned a few hundred meters to south. This location falls within a wildlife observation cluster. Alternatively, the fence could end just before the cliff on the west side and where the river departs the road (about 47.2), leaving the cliff unmitigated.
52.6-52.7	Wide and high over span bridge	Elk, moose, black bear, white-tailed deer, mule deer, coyote, wolf, (grizzly bear)	This may be an existing bridge (minimal costs) across Wardle creek.
55.5.55.6	Large mammal underpass	Elk, moose, black bear, white-tailed deer, mule deer, coyote, wolf	This may be a difficult location because of slope on west side.
61.6-61.7	Large mammal underpass	Black bear, elk, moose, white-tailed deer, coyote, pine marten, (grizzly bear)	This location falls within a wildlife observation cluster.
62.4-62.5	Wide and high	Black bear, elk, moose,	This is an existing bridge (minimal costs)

	over span bridge	white-tailed deer, coyote, pine marten, (grizzly bear)	(Vermilion Crossing). This location falls within a wildlife observation cluster.
71.0-71.1	Large mammal underpass	Elk, black bear, white-tailed deer, moose, porcupine, coyote, (grizzly bear)	Hawk creek, combine with creek crossing
74.6-74.7	Large mammal underpass	Elk, black bear, white-tailed deer, moose, porcupine, coyote, (grizzly bear)	
92.8-92.9	Large mammal underpass	Elk, moose, bighorn sheep, black bear, white-tailed deer, wolf	Combine with creek crossing

APPENDIX K: SUGGESTED SAFE CROSSING OPPORTUNITIES WITHIN THE MITIGATION ZONES IN AND AROUND RADIUM HOT SPRINGS

Road unit	Safe Crossing Opportunity	Primary target species	Comments
Radium Hot Springs South 1.8-1.9	Wildlife overpass	Bighorn sheep	Alternatively, a large mammal underpass at 1.9-2.0.
Radium Hot Springs North 0.2-0.5	Animal detection system (perhaps start at 0.1 until 0.4, on both sides of the road)	Bighorn sheep	Alternatively, a large mammal underpass at 0.3, with wildlife fencing starting 100 m from Jct Hwy 93/95 on Forsters Landing Road until 0.4 (on Radium Hot Springs North, until Jct with Sinclair Creek Loop Road)

APPENDIX L: NUMBER OF OBSERVATIONS PER SPECIES PER 100 M ROAD UNIT IN THE MITIGATION ZONES IN KOOTENAY AND BANFF NATIONAL PARK

Road unit	Badger	Bear	Beaver	Black bear	Bobcat	Cougar	Coyote	Deer	Elk	Goat	Grizzly bear	Hoary marmot	Lynx	Marten	Moose	Mule deer	Porcupine	Red fox	Sheep	Skunk	Snowshoe hare	W-tailed Deer	Wolf	Wolverine
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	14	0	0	0	0	0
2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0
2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
2.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
2.5	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	10	0	0	0	0	0
2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0
2.7	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0
2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	17	0	0	0	0	0
2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8	0	0	0	0	0
3.0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	6	0	0	0	0	0
3.2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	7	0	0	0	0	0
3.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
3.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0
3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
3.7	0	0	0	8	0	0	1	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
3.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.9	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
4.0	0	0	0	2	0	0	0	1	1	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
4.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
4.2	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0
4.3	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
4.4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
4.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
4.6	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
4.7	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
4.9	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0
5.1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0
5.2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
5.3	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
5.5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.6	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
5.7	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0

5.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.9	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.1	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
6.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0
6.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
6.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0
6.9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
7.0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
7.1	0	0	0	5	0	0	1	0	0	0	0	0	0	0	1	9	0	0	7	0	0	1	1	0
7.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
7.3	0	0	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7.8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
7.9	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
8.0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.1	0	0	0	5	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0
8.2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
8.3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.4	0	0	0	7	0	0	1	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
8.5	0	0	0	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
8.6	0	0	0	6	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0
8.7	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
8.8	0	1	0	3	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.9	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
9.0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.2	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
9.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
9.5	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
10.0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0
10.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0
10.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
10.3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0
10.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
10.5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.6	0	0	0	2	0	0	0	1	0	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0

10.7	0	0	0	8	0	0	0	0	1	0	0	0	0	0	0	1	0	0	4	0	0	0	1	0
10.8	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
10.9	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
11.0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
11.1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.2	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
11.3	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
11.4	0	0	0	9	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
11.5	0	0	0	9	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.7	0	0	0	22	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.8	0	0	0	18	0	0	1	0	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0
11.9	0	0	0	7	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.0	0	0	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.1	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12.2	0	0	0	3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.3	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
12.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.5	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.6	0	0	0	3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.7	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12.8	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
12.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.1	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
13.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
13.3	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
13.4	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
13.5	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.6	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13.7	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
13.8	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
13.9	0	0	0	5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
14.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.3	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14.4	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
14.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
14.6	0	0	0	5	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
14.7	0	0	0	12	0	0	1	0	3	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0
14.8	0	0	0	10	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
14.9	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
15.0	0	0	0	3	0	0	2	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0
15.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	0	1	0	0	0
15.2	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
15.3	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.4	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0
15.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

15.6	0	0	0	6	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
15.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15.8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15.9	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0
16.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
16.2	0	0	0	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
16.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.5	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.6	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
16.8	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
17.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
17.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
17.4	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0
17.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
17.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
17.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
17.8	0	0	0	2	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
17.9	0	0	0	4	0	0	1	0	3	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
18.0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5	0	0
18.1	0	0	0	6	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
18.2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	3	0	0
18.3	0	0	0	3	0	0	1	0	1	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0
18.4	0	0	0	11	0	0	0	0	9	0	0	0	0	0	1	0	0	0	0	0	0	7	0	0
18.5	0	0	0	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
18.6	0	0	0	6	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
18.7	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
18.8	0	0	0	4	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	1	0	0
18.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19.0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
19.1	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
19.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
19.3	0	0	0	2	0	0	0	0	5	0	0	0	0	0	1	1	0	0	0	0	0	3	0	0
19.4	0	0	0	2	0	0	1	0	0	0	0	0	0	0	3	1	0	0	0	0	0	3	1	0
19.5	0	0	0	0	0	0	0	0	2	0	0	0	0	1	4	0	0	0	0	0	0	2	0	0
19.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
19.8	0	0	0	1	0	0	1	0	2	0	0	0	0	0	2	2	0	0	0	0	0	1	0	0
19.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	2	0	0	0	0	0	1	0	0
20.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
20.1	0	0	0	1	0	0	1	0	9	0	0	0	0	0	3	0	0	0	0	0	0	5	0	0
20.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0
20.3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
20.4	0	0	0	1	0	0	0	0	2	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0

20.5	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
20.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
20.7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
20.8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
20.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0
21.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
21.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
21.3	0	0	0	0	0	0	1	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
21.4	0	0	0	2	0	0	1	0	2	0	0	0	0	0	1	2	0	0	0	0	0	4	1	0
21.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5	0	0
21.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	1	0
21.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0
21.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
21.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
22.1	0	0	0	0	0	0	1	0	12	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
22.2	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
22.3	0	0	0	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
22.5	0	0	0	1	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
22.6	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.7	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
22.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
23.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
23.1	0	0	0	3	0	0	2	0	21	0	0	0	0	0	0	2	0	0	0	0	0	5	0	0
23.2	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0
23.3	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
23.4	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
23.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
23.6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
23.7	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.8	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0
23.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
24.1	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
24.2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
24.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
24.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
24.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
24.8	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
24.9	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
25.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
25.2	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
25.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0

25.4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
25.5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
25.6	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
25.7	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
25.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
25.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
26.0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
26.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
26.2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9	1	0
26.3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	9	0	0
26.4	0	0	0	2	0	0	1	0	26	0	0	0	0	0	0	1	0	0	0	0	0	8	0	0
26.5	0	0	0	7	0	0	2	0	8	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0
26.6	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	8	0	0
26.7	0	0	0	3	0	0	1	1	3	0	0	0	0	0	0	1	0	0	0	0	0	6	0	0
26.8	0	0	0	2	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
26.9	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
27.0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0
27.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0
27.3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	6	0	0
27.4	0	0	0	0	0	0	1	0	15	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0
27.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
27.6	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
27.7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
27.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27.9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
28.0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
28.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
28.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
28.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
28.5	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0
28.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
28.7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
28.9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
29.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
29.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
29.2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0
29.4	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
29.5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0
29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	8	0	0
29.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29.8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0
29.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
30.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
30.2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0

30.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
30.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
30.5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
30.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
30.7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0
30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
30.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
31.1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
31.2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
31.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
31.4	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
31.5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0
31.6	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
31.7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
31.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31.9	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
32.0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
32.1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
32.2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	7	0	0
32.3	0	0	0	1	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
32.4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
32.5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	4	1	0
32.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0
32.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
32.8	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	1	0	0	0	0	0	6	0	0
32.9	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0
33.0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8	2	0
33.1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0
33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0
33.3	0	0	0	6	0	0	1	0	17	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0
33.4	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0
33.5	0	0	0	4	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	10	0	0
33.6	0	0	0	4	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	17	2	0
33.7	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0
33.8	0	0	0	3	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0
33.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
34.0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0
34.1	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0
34.2	0	0	0	1	0	0	3	0	17	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0
34.3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
34.4	0	0	0	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	8	0	0
34.5	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
34.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
34.7	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5	2	0
34.8	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0
34.9	0	0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0
35.0	0	0	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0
35.1	0	0	2	1	0	0	0	1	14	0	0	0	0	0	0	1	0	0	0	0	0	12	0	0

35.2	0	0	1	4	0	0	2	1	1	0	0	0	0	0	1	1	0	0	0	0	0	14	0	0
35.3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5	0	0
35.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	9	0	0
35.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0
35.6	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	4	0	0
35.7	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0
35.8	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5	1	0
35.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
36.0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
36.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
36.2	0	0	0	1	0	0	1	0	4	0	0	0	0	0	1	1	0	0	0	0	0	7	0	0
36.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
36.4	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	9	0	0
36.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
36.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
36.7	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	7	0	0
36.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7	1	0
36.9	0	0	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	14	1	0
37.0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	11	1	0
37.1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
37.2	0	0	0	3	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0
37.3	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7	1	0
37.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	1	0
37.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	7	0	1
37.6	0	0	0	2	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0
37.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
37.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
37.9	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
38.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
38.2	0	0	0	2	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0
38.3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
38.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
38.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
38.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	1	0
38.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
38.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0
39.0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
39.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
39.2	0	0	0	1	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
39.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
39.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
39.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
39.6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
39.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
39.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
39.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0

40.1	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	12	1	0
40.2	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	2	0	0	0	0	0	12	1	0
40.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0
40.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0
40.5	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
40.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	6	0	0
40.7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	12	0	0
40.8	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
40.9	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
41.0	0	0	0	2	0	0	0	1	2	0	0	0	0	0	2	0	0	0	0	0	0	1	1	0
41.1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
41.2	0	0	0	4	0	0	1	1	7	0	0	0	0	0	0	2	0	0	0	0	0	11	0	0
41.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
41.4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
41.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
41.6	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0
41.7	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
41.8	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0
41.9	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
42.0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	7	0	0
42.1	0	0	0	9	0	0	0	0	4	0	0	0	0	1	2	0	0	0	0	0	0	5	3	0
42.2	0	0	0	8	0	0	3	0	14	0	0	0	0	0	0	1	0	0	0	0	0	6	5	0
42.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
42.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
42.5	0	0	0	1	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
42.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0
42.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
42.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
42.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
43.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
43.1	0	0	0	2	0	0	1	1	8	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
43.2	0	0	0	0	0	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
43.3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	6	0	0
43.4	0	0	0	2	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
43.5	0	0	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	0	0	8	2	0
43.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
43.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
43.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
43.9	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
44.0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44.1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
44.2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0
44.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
44.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
44.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
44.6	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
44.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0
44.8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
44.9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0

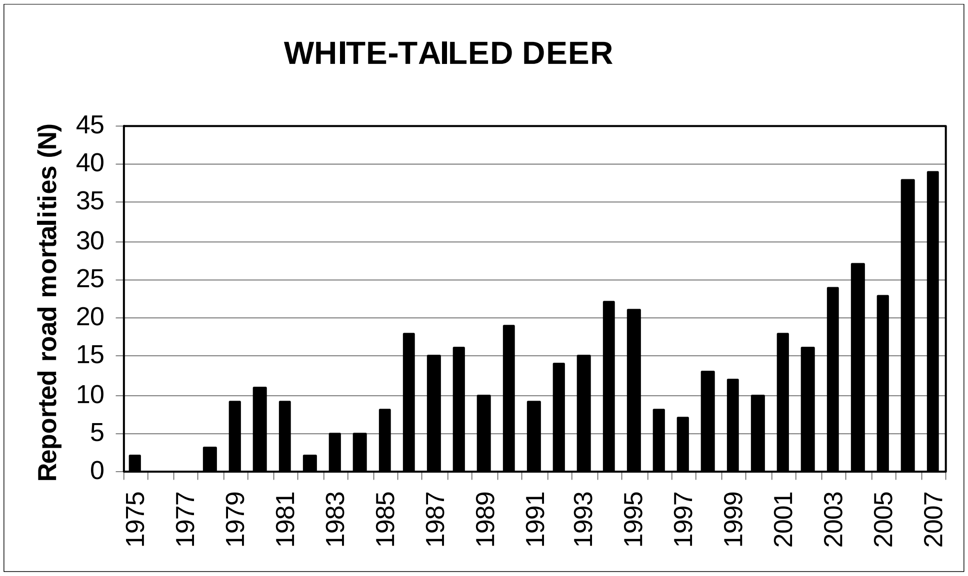
45.0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
45.1	0	0	0	0	0	0	2	0	9	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
45.2	0	0	0	1	0	0	1	0	3	0	1	0	0	0	0	0	0	0	0	0	0	5	0	0
45.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
45.4	0	0	0	2	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0
45.5	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0
45.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
45.7	0	0	0	0	0	0	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	4	1	0
45.8	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
45.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
46.0	0	0	0	4	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
46.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46.2	1	0	0	3	0	0	1	1	15	0	0	0	0	0	0	1	0	0	0	0	0	4	2	0
46.3	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
46.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
46.5	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
46.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46.8	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
46.9	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0
47.0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0
47.1	0	0	0	0	0	0	1	0	4	8	0	0	0	0	0	0	0	0	3	0	0	0	3	0
47.2	0	0	0	0	0	0	0	2	8	23	0	0	0	0	0	0	0	0	1	0	0	0	1	0
47.3	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	0	0	0	1	0	0	0	1	0
47.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
47.5	0	0	0	1	0	0	1	0	5	3	0	0	0	0	1	1	0	0	0	0	0	0	0	0
47.6	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47.7	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
47.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0
47.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48.0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
48.2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
52.2	0	0	0	1	0	0	0	0	9	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
52.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
52.4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52.6	0	0	0	1	0	0	0	0	2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
52.7	0	1	0	2	0	0	1	0	1	0	0	0	0	0	1	1	0	0	0	0	0	2	0	0
52.8	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0
52.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53.1	0	0	0	0	0	0	2	0	8	0	0	0	0	0	1	1	0	0	0	0	0	3	0	0
53.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
53.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
53.4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
53.5	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
53.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

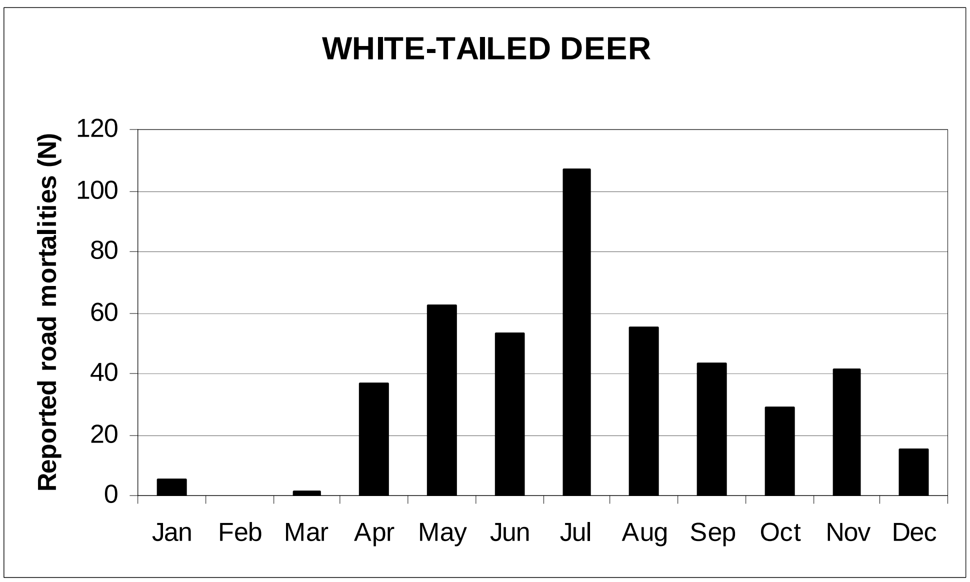
53.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
54.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
54.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	1	0
54.6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
54.7	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
54.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
55.0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0
55.1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0
55.2	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
55.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0
55.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	2	0	0
55.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
55.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55.7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
55.8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
55.9	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
56.0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56.3	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
60.5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
60.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
60.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
61.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
61.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61.2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
61.3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
61.4	0	0	0	2	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
61.5	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61.6	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
61.7	0	0	0	1	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	2	0	0
61.8	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
61.9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62.0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
62.1	0	1	0	4	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0
62.2	0	0	0	0	0	0	0	1	1	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0
62.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

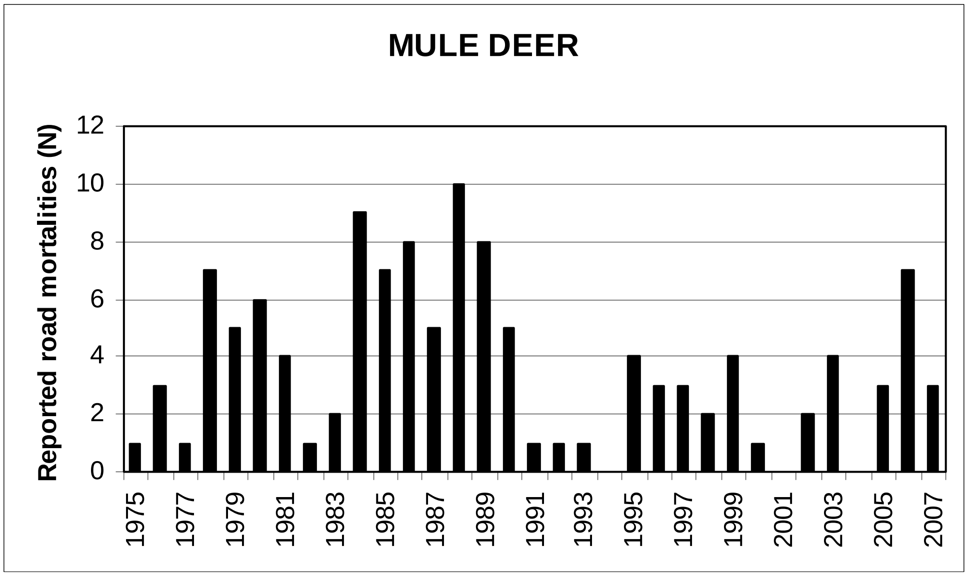
62.5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62.6	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62.7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
62.8	0	0	0	2	0	0	1	0	1	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0
69.9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70.0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
70.1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70.2	0	0	0	1	0	0	0	0	8	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
70.3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
70.4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
70.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
70.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
70.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
70.8	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
70.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71.0	0	0	0	1	0	0	0	1	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
71.1	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
71.2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
71.3	0	0	0	3	0	0	0	0	7	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0
71.4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
71.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71.6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
71.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
72.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
72.2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
72.3	0	0	0	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
72.5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
72.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
72.9	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
73.2	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.4	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73.8	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
73.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
74.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
74.1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
74.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
74.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

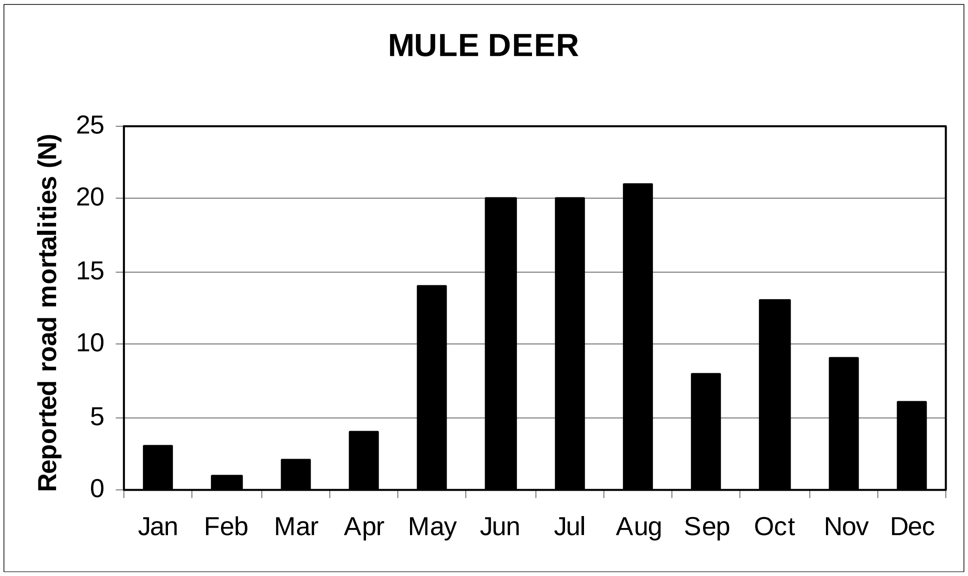
74.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0
74.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0
74.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
74.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
75.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
75.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
75.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
75.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
91.9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1
92.1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92.2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92.3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	2	1	0
92.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92.5	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
92.6	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0
92.7	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
92.8	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0
9.9	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	2	0	0	0	1	0
9.8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
9.7	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
9.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
9.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
9.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

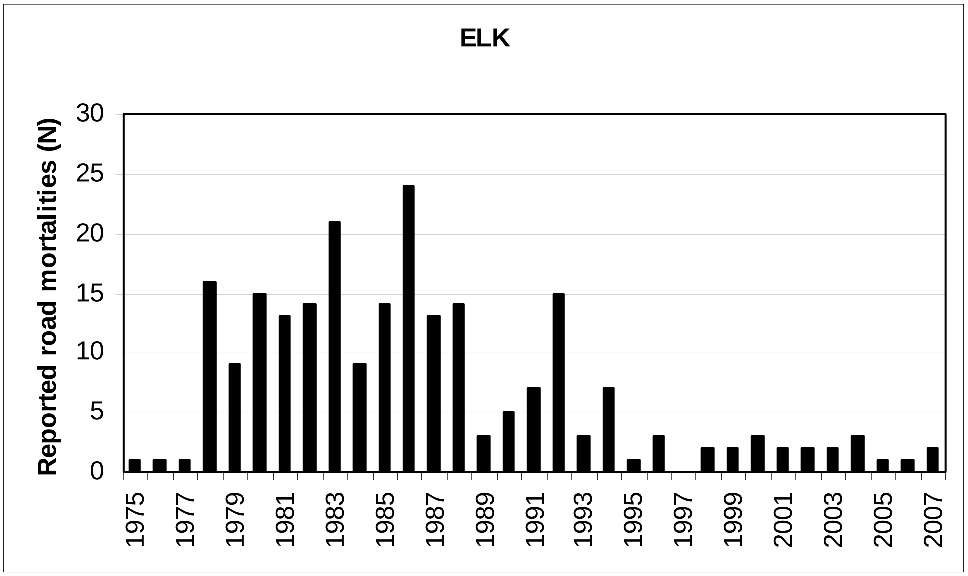
APPENDIX M: NUMBER OF ROAD-KILL OBSERVATIONS PER SPECIES IN KOOTENAY AND BANFF NATIONAL PARK PER YEAR (BETWEEN 1975 AND 2007) AND PER MONTH (WITHIN 100 M FROM HWY)

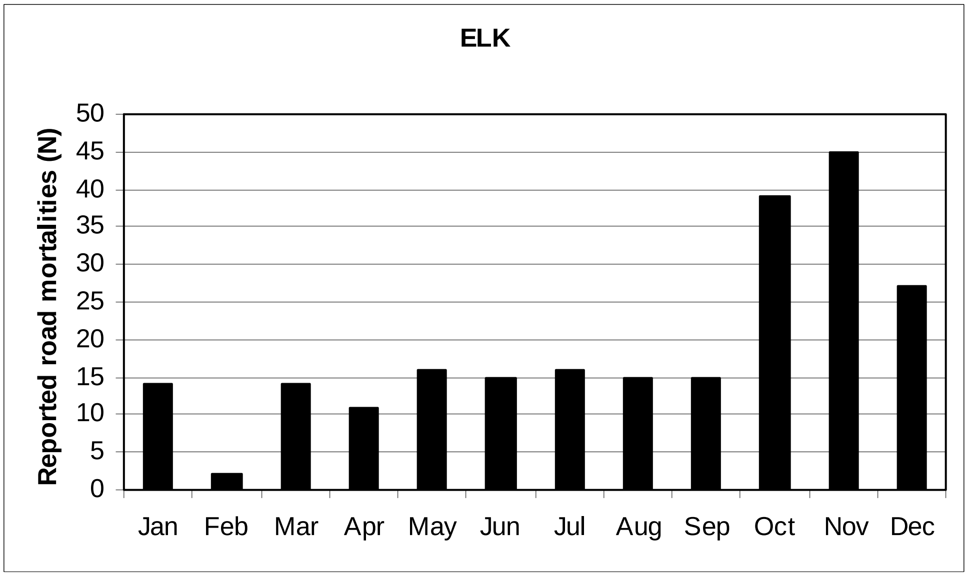


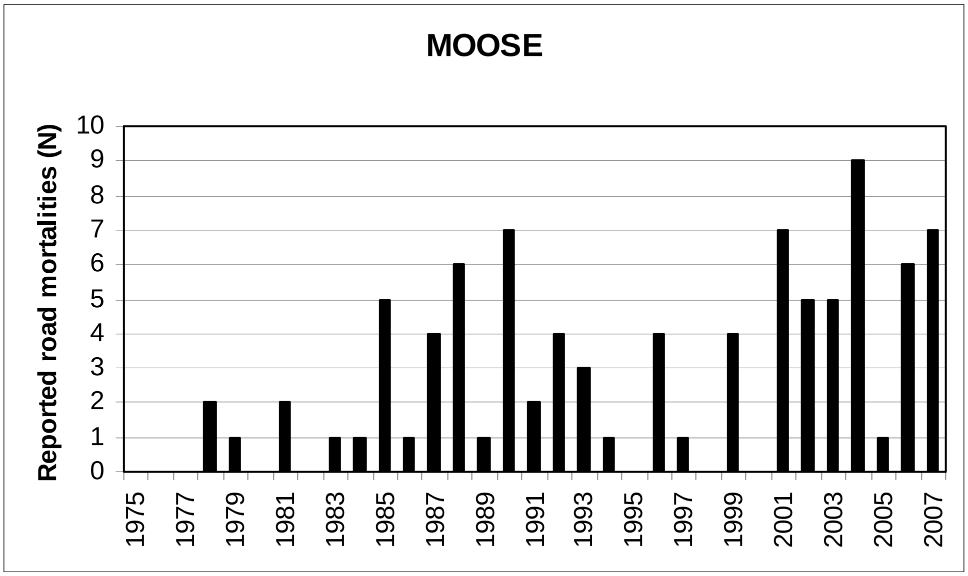


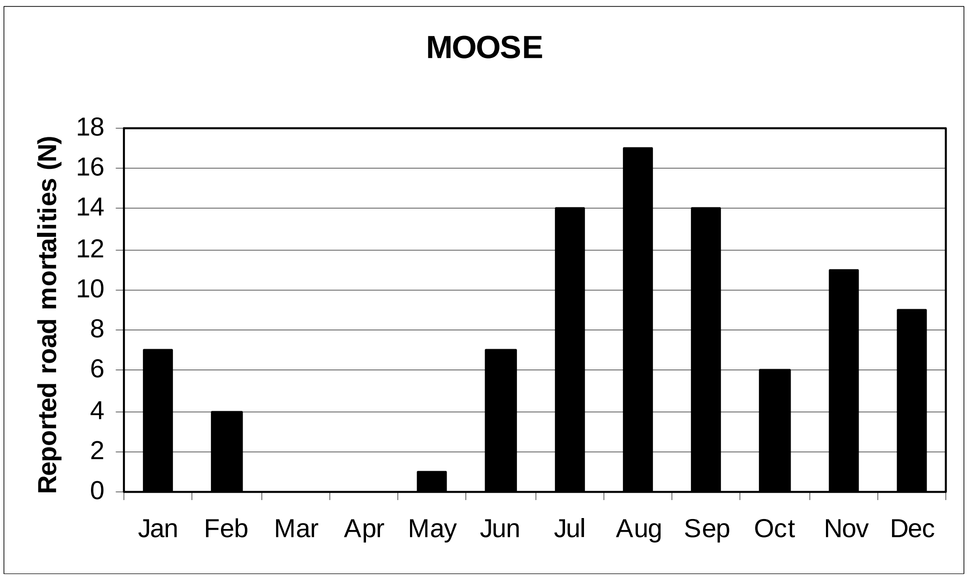

MULE DEER
Reported road mortalities (N)
0
2
4
6
8
10
12
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

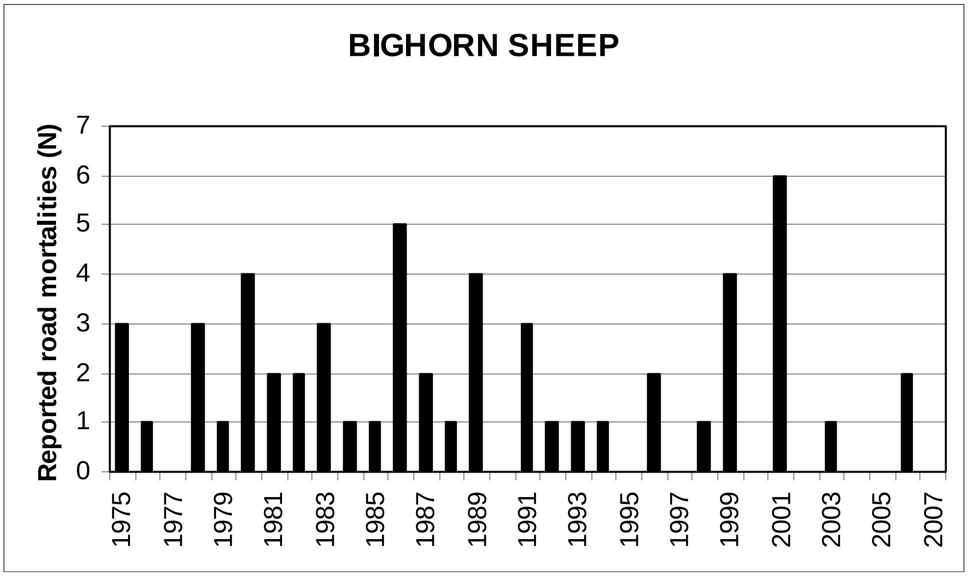

MULE DEER
Reported road mortalities (N)
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

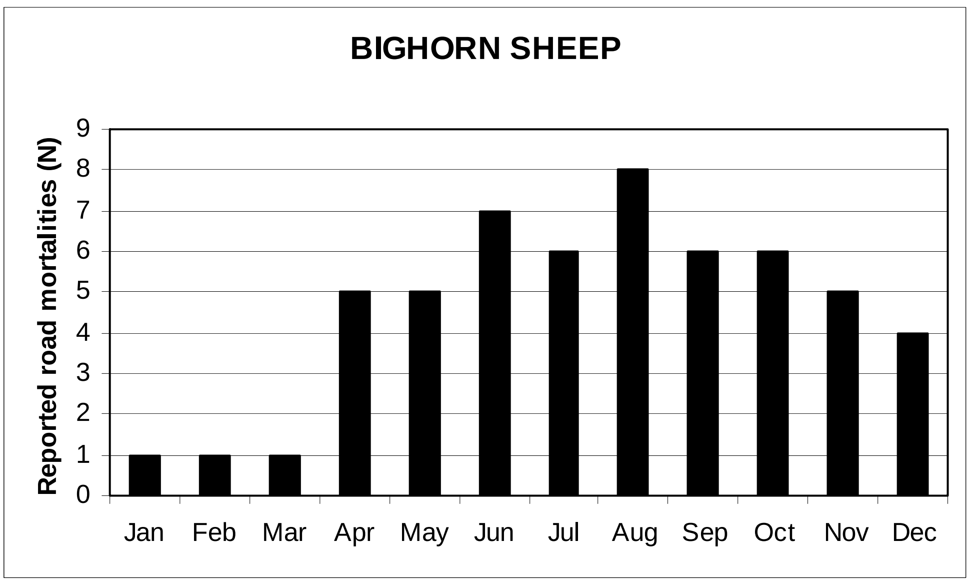

ELK
Reported road mortalities (N)
0
5
10
15
20
25
30
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007

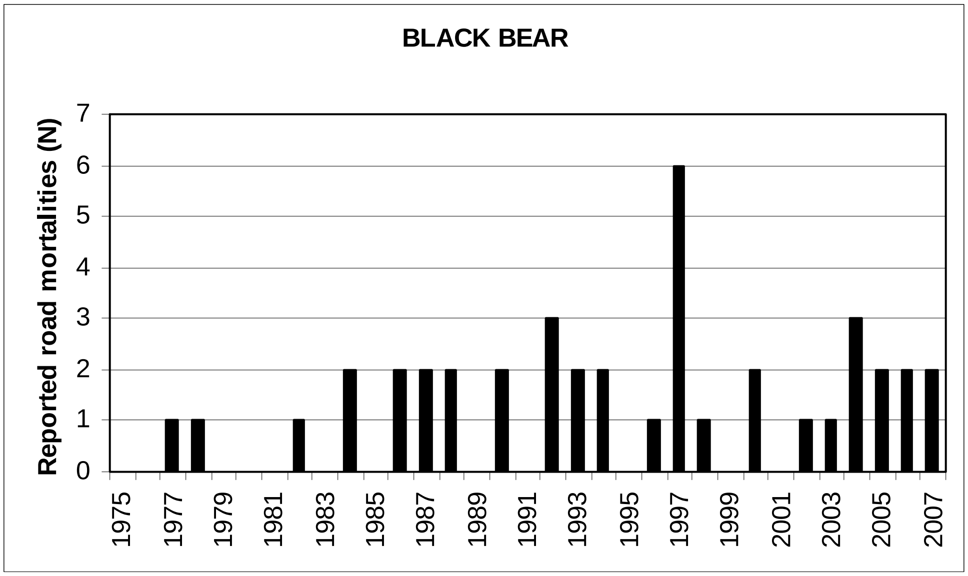

ELK
Reported road mortalities (N)
0
5
10
15
20
25
30
35
40
45
50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

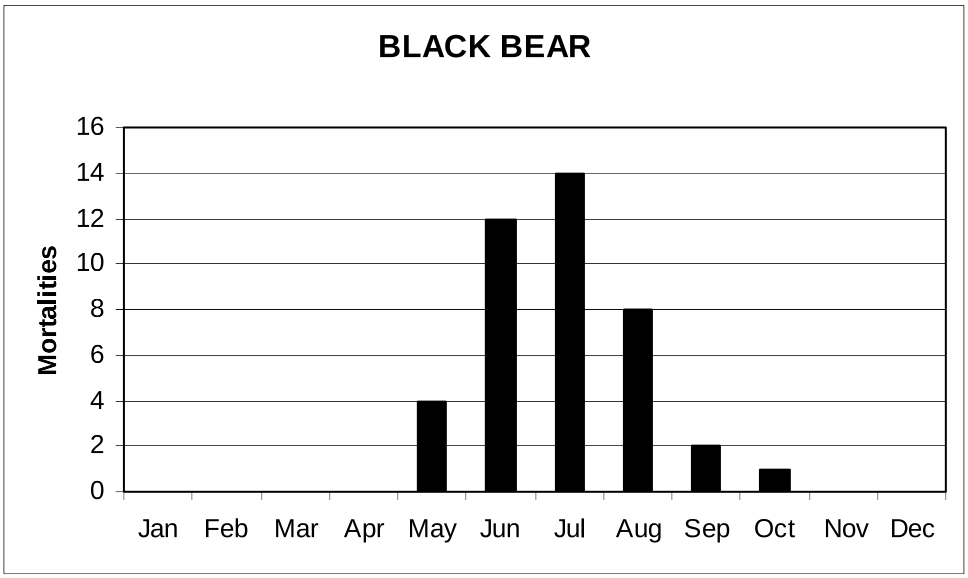

MOOSE
Reported road mortalities (N)
0
1
2
3
4
5
6
7
8
9
10
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007


MOOSE
Reported road mortalities (N)
0
2
4
6
8
10
12
14
16
18
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


BIGHORN SHEEP
Reported road mortalities (N)
0
1
2
3
4
5
6
7
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007


BIGHORN SHEEP
Reported road mortalities (N)
0
1
2
3
4
5
6
7
8
9
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


BLACK BEAR
Reported road mortalities (N)
0
1
2
3
4
5
6
7
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007


BLACK BEAR
Mortalities
0
2
4
6
8
10
12
14
16
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

APPENDIX N: NUMBER OF ROAD-KILL OBSERVATIONS OF BIGHORN SHEEP IN AND AROUND RADIUM HOT SPRINGS PER YEAR (BETWEEN 1975 AND 2007) AND PER MONTH (WITHIN 100 M FROM HWY)