Mortality and Live Observations of Wildlife on and Along the Yellowhead Highway and the Railroad through Jasper National Park and Mount Robson Provincial Park, Canada

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16. Abstract

This project focuses on providing a strategy for the potential future implementation of wildlife mitigation measures along the Yellowhead highway (Hwy 16) and the railroad through Jasper National Park (JNP) and Mount Robson Provincial Park (MRPP). The general objectives of the mitigation measures are to reduce direct wildlife mortality of medium and large carnivore species on Hwy 16 and the railroad and to maintain or improve habitat connectivity for wildlife, specifically medium and large carnivore species, across Hwy 16 and the railroad.

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EXECUTIVE SUMMARY

This project focuses on providing a strategy for the potential future implementation of wildlife mitigation measures along the Yellowhead highway (Hwy 16) and the railroad through Jasper National Park (JNP) and Mount Robson Provincial Park (MRPP). The general objectives of the mitigation measures are to reduce direct mortality of medium and large carnivore species on Hwy 16 and the railroad and to maintain or improve habitat connectivity for wildlife, specifically medium and large carnivore species, across Hwy 16 and the railroad. This summary is organized according to the specific objectives for this project:

1. Obtain existing wildlife road and railroad mortality and movement data as well as knowledge and experience from local experts for Hwy 16 and the railroad through JNP and MRPP.

The researchers obtained road and railroad mortality data and life observation data from different sources, including Parks Canada, British Columbia Ministry of Environment, British Columbia Ministry of Transportation, and Canadian National Railway Company. After initial examination of the data the researchers found there to be likely problems with the search and reporting efforts for wildlife-vehicle collisions through animal carcass data. Underreporting for wildlife-vehicle collisions along Hwy 16 and the railroad through MRPP appears to be a problem. While underreporting of wildlife-vehicle collisions occurs almost everywhere and is not necessarily a problem as long as the search and reporting effort is consistent, the researchers feel that the search and reporting effort in MRPP may be too low to produce useful results without applying large and potentially inaccurate corrections to compensate for likely underreporting.

2. Analyze the data mentioned above to identify high mortality and live observation areas for the focal species (carnivores and woodland caribou).

Because the search and reporting effort appeared to vary substantially between JNP and MRPP and also between Hwy 16 and the railroad, the researchers conducted separate analyses to identify and prioritize the road and railroad sections in the two parks for the potential implementation of mitigation measures. The mitigation measures are aimed at reducing direct mortality for the focal species (fisher, wolverine, Canada lynx, cougar, red fox, coyote, wolf, black bear, grizzly bear and caribou) and to allow for safe crossing opportunities for the focal species and selected other species (focal species and (other) large ungulates). The researchers are of the opinion that the identification and prioritization of road and railroad sections that may qualify for mitigation measures was relatively robust for Hwy 16 and the railroad through JNP. However, the identification and prioritization of road and railroad sections through MRPP is likely not very robust because of the scarcity of the data.

Based on the available data the researchers calculated that at an average of 19.4 individuals of the focal species (carnivores and caribou) and 130.9 (other) ungulates (white-tailed deer, mule deer, elk, moose, mountain goat, and bighorn sheep) per year are reported killed by vehicles or trains along Hwy 16 or the railroad through JNP and MRPP. The mortality data for the focal species were used to identify mortality clusters. Mortality clusters consisted of the “worst” 20% of the 0.1 km road or railroad segments with at least one wildlife mortality over a 10 year period

(2000 through 2009) and the adjacent worst 40% of the 0.1 km road or railroad segments. The mortality clusters were ranked based on the average number of focal species reported per 100 m road or railroad length in a mortality cluster. The mortality clusters along Hwy 16 were widespread, but a relatively high concentration occurs between the Jasper town site and the Snaring River with the two worst mortality clusters between km markers 43.1-43.4 and 42.4-42.8. The mortality clusters along the railroad are less concentrated, but the worst cluster is between km markers 52.9-53.1.

Potential locations for safe crossing opportunities were identified through combining wildlife mortality data with live wildlife observations of the focal species and (other) large ungulates observed from 1951 through 2009. Since live observations were only available within JNP, the analyses were restricted to the road and railroad in JNP. It is important that locations for safe crossing opportunities are not only based on where animals are killed. If safe crossing opportunities are only provided on road sections where a concentration of wildlife-vehicle collisions occurs and if fences are constructed between these crossing opportunities, locations where wildlife may currently cross the road successfully may become an absolute barrier. Therefore both dead and alive observations were used in these analyses and the analyses included not only the focal species but also other large mammals, specifically large ungulates. Through basing the observation cluster on the longest time period possible their location is as robust as possible. It incorporates, at least to a certain extent, the dynamics in the ecosystem, including natural succession, fire, and changes in the population size of certain species. This is important as concrete structures have a projected life span of 75 years and should provide a safe crossing opportunity over a long time period. Observation clusters consisted of the "highest" 20% of the 0.1 km road or railroad segments with at least one wildlife observation over the time period concerned and the adjacent highest 40% of the 0.1 km road or railroad segments. The observation clusters were ranked based on the average number of observations reported per 100 m road or railroad length in an observation cluster. The observation clusters along Hwy 16 and the railroad were widespread, but a relatively high concentration occurs between the Jasper town site and the Snaring River with the highest ranking observation cluster along Hwy 16 between km markers 29.8-30.9 and along the railroad between km markers 25.4-25.6.

3. Discuss the implication of the transportation mortality for the focal species based on existing data and expert opinion, and prioritize locations based on this analysis.

The researchers investigated whether population persistence of the focal species in JNP and MRPP may be affected by road and railroad mortality within these parks. Given the available budget the researchers chose a relatively simple step-by-step quick-scan approach that allowed for the identification of functional habitat networks and an evaluation of the persistence of the network population for each focal species. The population persistence assessment was conducted for the two protected areas (JNP and MRPP) combined and ignored the potential presence of populations in adjacent areas outside the two parks. The researchers consider this justified as land and wildlife management is likely to be different in the areas outside the two parks which may result in (much) lower population densities and at least a certain degree of isolation from the populations in the two parks. Most importantly, the two parks have no jurisdiction in the unprotected areas. Thus one could argue that it is up to the management of the two parks to see if the two parks can have wildlife populations persist under different management strategies, or whether the areas of the two parks (and therefore the wildlife populations) are simply too small to have populations persist independent from the presence of populations in the neighboring areas that may be unprotected.

The researchers considered a range of possible population densities and therefore possible population sizes for the focal species in JNP and MRPP. The researchers also considered different percentages of the population to consist of reproductive females (Reproductive Units (RU) is either 30% or 50%) and considered the two main roads to be at least somewhat of a barrier to the movements of the focal species or not at all. Each combination of population size estimate and percentage of RUs and each population structure scenario resulted in an estimate for the population persistence of the focal species. Based on the results one may conclude that it is more likely or less likely that an individual focal species has a persistent population in JNP or MRPP if the two parks are considered an island and isolated from potential populations in the adjacent areas.

In all of the combinations and scenarios and under all assumptions wolf seems to be especially vulnerable and direct road and railroad mortality appears to be relatively high compared to the number of reproductive units and their population size. Fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou may or may not have persistent populations in JNP and MRPP depending on the scenario and assumptions one chooses to accept. The population persistence of the species listed above may well depend on the presence, size, and connectivity with populations in the areas adjacent to JNP and MRPP. One could argue that any road or railroad mortality that occurs would be undesirable for these species and that it further threatens their population persistence within the two parks. This could provide a framework, rationale or justification to implement mitigation measures along the road and railroad for these species. Coyote and black bear are most likely to have persistent populations in JNP and MRPP and may not be affected very much by direct road and railroad mortality.

The method used for assessing population persistence can be characterized as a “quick-scan”. The advantage of this quick scan method is that selected areas can be evaluated relatively quickly and easily for the population persistence of a multitude of species. The disadvantage of the quick scan method is of course a relatively high level of uncertainty. The use of a simple set of rules and standards makes the method sensitive to small alterations in the parameter values. The researchers at least partly counteracted this disadvantage through calculating population persistence for a range of parameter combinations reflecting a spread from worst-case to best-case scenarios. This provides insight in the robustness of the outcomes for the combinations and scenarios that is assumed to reflect reality best. Another disadvantage is that the use of standards (thresholds) results in a “black and white” type of assessment. This should be taken into account when interpreting the outcomes, especially when parameter values almost or just meet the thresholds. Because of these disadvantages of the method, the outcome of the assessment should never be interpreted as a precise but rather an indicative prediction of population persistence within JNP and MRPP.

The researchers suggest conducting more extensive and formal population viability analyses (PVAs), using dynamic (meta)population models, especially for the wolf, but also for fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou. Coyote and black bear can be considered less of a priority for further research. Alternatively one can use the results of the current study as a rationale to start implementing mitigation measures aimed at reducing direct road and railroad mortality and providing safe crossing opportunities for wildlife, especially for wolf, fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou.

4. Identify suitable mitigation measures and provide cost estimates for the implementation of these mitigation measures.

The researchers suggest large overspan bridges and large mammal underpasses for most mitigation zones, and wildlife overpasses for other mitigation zones where grizzly bears have been observed most frequently along the road or railroad. A cost-benefit analyses for four different types and combinations of mitigation measures, including wildlife fencing, underpasses, overpasses, and animal detection systems, showed that there are a number of road sections along Hwy 16 in JNP where mitigation measures may generate economic benefits in excess of costs. There are no such road sections along Hwy 16 through MRPP though. This is most likely related to the scarcity of the data for this road section.

5. Review existing wildlife observation databases and monitoring programs and provide recommendations for potential improvements, including for the evaluation of the effectiveness of potential future mitigation measures.

The researchers provide recommendations for ongoing road and railroad mortality data collection programs. Specific recommendations for the data collection programs in MRPP are to increase the search and reporting effort for road and railroad mortalities, to specify the species, particularly for bear species, and to increase the spatial accuracy of the data. For GPS based systems it is important to note the road or railroad on which the animal was struck as the observation location may not be on or near the road. Data on the age and gender of individuals may prove to be very useful for potential future population viability modeling.

Observations of live animals are particularly useful to identify locations where animals may cross the road most frequently. This is important because locations where animals are killed by vehicles or trains are not necessarily the same locations where they cross the road successfully, and these locations should not inadvertently be blocked, e.g. through wildlife fences. There is an ongoing program for observations of live animals in JNP, but it may be advisable to standardize the search and reporting effort along the entire length of Hwy 16 and the railroad (e.g. through regular drives by Parks Canada personnel or railroad personnel for other purposes). Such a data collection system would have to be initiated in MRPP.

1. INTRODUCTION

1.1 Background

Between August 2007 and October 2008 the Kinder Morgan Canada oil pipeline (the former TMX oil pipeline) was twinned through Jasper National Park (JNP) and Mount Robson Provincial Park (MRPP). The Kinder Morgan Canada's Trans Mountain Legacy Fund was put in place in conjunction with the twinning project to improve the ecological integrity of Jasper National Park (JNP) and Mount Robson Provincial Park (MRPP). Potential projects that meet the objective of the fund were identified and prioritized through an analytical hierarchy process with local and regional environmental stakeholders (Clevenger et al., 2009). The current work is partially based on this list of suggested projects and is aimed at: investigating whether direct wildlife mortality along the Yellowhead Highway (Hwy 16) and the railroad in JNP and MRPP is affecting its carnivore populations; and identifying mitigation measures to avoid or reduce these impacts. For the purpose of this report "the transportation corridor" is defined as Hwy 16 and the railroad through JNP and MRPP (Figure 1). Hwy 16 and the railroad run parallel to each other and are roughly oriented east-west. Other roads through JNP and MRPP such as the Icefields Parkway (Hwy 93) are not included in the analyses. The Kinder Morgan Canada oil pipeline that parallels Hwy 16 and the railroad was also excluded because it is not a direct collision mortality source.

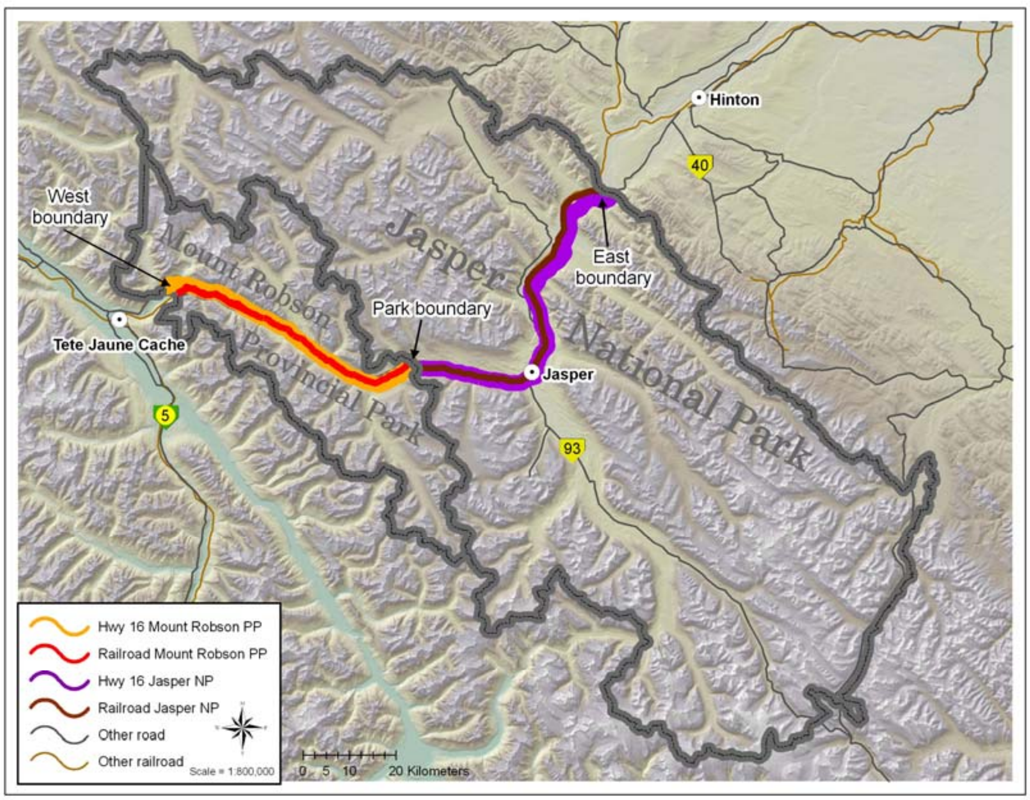

Figure 1. The east-west transportation corridor that is included this study: The Yellowhead Highway (Hwy 16) and the railroad through Jasper National Park and Mount Robson Provincial Park. The length of Hwy 16 through JNP and MRPP is 140.2 km and the length of the railroad is 153.8 km (including the 16.8 km long Robson section of the railroad that splits off at Red Pass).

1.2 Effects of Transportation Infrastructure on Wildlife and Mitigation Strategies

Transportation corridors impact wildlife in different ways. Four general types of effects can be distinguished (e.g. see reviews in Forman et al. (2003) and Beckman et al. (2010)):

- Direct loss of habitat: The presence of a road, railroad, and adjacent right-of-ways involves removal and alteration of native vegetation, along with soil and hydrological disturbances. This typically causes complete habitat loss for wildlife in the areas that are paved and the remaining disturbed areas alongside the pavement may become unsuitable for certain wildlife species and suitable for others.
- Direct mortality: Collisions with cars or trains kill individual animals, sometimes in great numbers. Wildlife-vehicle collisions can also pose a threat to human safety, especially when the wildlife species involved is large and heavy.
- Reduced habitat quality on either side of a transportation corridor: Pollutants, or disturbance associated with noise, light, cars or humans may make a zone adjacent to a transportation corridor less suitable or attractive to certain species. Dependent on the species and variable concerned this zone with reduced habitat quality may be a few meters up to a few kilometers wide.
- The barrier effect of a transportation corridor: Some species or individuals may substantially reduce their attempts to cross a transportation corridor, potentially leading to more isolated and smaller populations on either side of the transportation corridor.

Most of the processes described above can be summarized by the term “habitat fragmentation” as they relate to habitat loss, the decrease in habitat quality, and smaller and more isolated habitat patches that are more exposed to disturbance (“edge effects”). Combined with direct mortality, for example on transportation corridors, habitat fragmentation can affect the population viability of certain species. Smaller and more isolated populations may have reduced genetic variability, and are more susceptible to local or regional extinction due to stochastic processes affecting the number of reproducing individuals in a (sub)population. For example, a “disaster” or “combination of disasters” can cause the local or regional extinction of a species, partly because the population size is small already (e.g. Hebblewhite et al., 2009). In addition, re-colonization from elsewhere may not be possible or may be very slow due to the isolation of the habitat patches and reduced landscape connectivity. Species that are most vulnerable to this process are typically characterized by relatively large home ranges (especially when also territorial), low reproductive rate, low population density, low dispersal rate or short dispersal distances, habitat or food specialization, and being attracted (e.g. because of habitat or food) to dangerous areas such as transportation corridors which can develop into population sinks (e.g. Crooks, 2002). Most of these characteristics apply to large mammal carnivores, but smaller species, for example reptiles and amphibians are also known to have lower population viability because of direct mortality and habitat fragmentation processes (e.g. Cushman, 2006).

The negative effects of habitat fragmentation may be mitigated or compensated through:

- Increasing the size of existing habitat patches;
- Increasing the habitat quality of existing habitat patches;
- Creating new habitat patches, and;
- Increasing the connectivity between habitat patches.

In combination with reducing direct mortality all of these measures contribute to larger populations with increased ability to successfully move between different habitat patches in the landscape. Larger populations or a better connected network of subpopulations typically have greater genetic variability and higher population persistence probability.

When managing the negative effects of transportation corridors, it is important to be aware that these effects may not be addressed through mitigation only. Typically, the first step is to explore how the most severe effects may be avoided altogether (Cuperus et al., 1999). If avoidance is not an option, one may investigate the possibilities for mitigating (reducing) the effects. When that is not possible or insufficient either, the third step can be to investigate the potential for compensation (or "off-site mitigation"). Avoidance is not always considered an option as it may relate to not building a new transportation corridor or the rerouting of a corridor to less sensitive areas. Mitigation is often applied but only a few mitigation measures aimed at reducing wildlife road or railroad mortality are actually considered substantially effective (see Huijser et al. (2009) for a review).

Wildlife fencing in combination with wildlife under- and overpasses, as well as animal detection systems are considered the most effective mitigation measures for reducing wildlife-vehicle collisions (Huijser et al., 2008; Clevenger & Huijser, 2011). They appear to be able to reduce collisions with large mammals by 80% or more, but animal detection systems should be considered experimental and the estimate of their effectiveness in reducing wildlife-vehicle collisions may change as more data become available. Wildlife fencing keeps animals from entering the transportation corridor and reduces wildlife mortality on the transportation corridor. However, wildlife fencing alone increases the barrier effect of the transportation corridor, and it is considered good practice to always combine wildlife fencing with safe crossing opportunities for wildlife. The crossing opportunities may consist of wildlife underpasses and overpasses or at grade crossing opportunities; e.g. a gap in the fence, potentially combined with an animal detection system. Alternatively, animal detection systems can also be installed as a standalone mitigation measure over longer distances.

Compensation for the negative impacts of transportation infrastructure on wildlife may include increasing the size of existing habitat patches, increasing the habitat quality of existing habitat patches, creating new habitat patches, or increasing the connectivity between habitat patches. These compensation measures may be implemented at other locations that are further away from the road.

1.3 Current Situation in Jasper National Park and Mount Robson Provincial Park

Wildlife mortality along the roads and railroad through JNP and MRPP has been identified as a concern in both parks by the respective agencies (Ministry of Environment, Lands and Parks. Parks Division, 2001; Parks Canada 2008; 2010). An average of 170 animals (presumably large mammals only) per year were reported to have been killed on the highway and railway in JNP (Parks Canada, 2008). Most of the wildlife road mortality (about 80%) has been reported from the Yellowhead Highway (Hwy 16) that runs east-west through both JNP and MRPP. In JNP permanent and reduced speed zones and wildlife warning signs have been implemented along different road sections. The railroad has some sections with a wildlife fence and there is a wildlife guard at an entrance of a railroad tunnel towards the east end of JNP. Furthermore the park has been and is working with Canadian National Railway Company to minimize grain spills through updating grain cars and cleanup efforts when spills do occur (Parks Canada 2008; 2010). These efforts are aimed at reducing wildlife mortality along the transportation corridors. However, the speed zones and wildlife warning signs along roads appear not very effective (Parks Canada, 2008). Species and species groups that are specifically targeted to reduce human induced mortality are woodland caribou (*Rangifer tarandus*), grizzly bears (*Ursus arctos*) and carnivore species (Parks Canada 2010). It is recognized by Parks Canada that the roads and railroads not only negatively wildlife through direct mortality, but both terrestrial and wildlife species also suffer from habitat fragmentation (Parks Canada 2010). In addition, animals along the transportation corridors are habituated to non-natural food (e.g. active feeding along roads by the public, and grain spills along the railroad) and non-native plant species grow in the vegetation alongside the transportation corridors and spread into the adjacent areas. Furthermore the transportation corridors affect landscape aesthetics.

In MRPP Hwy 16 is recognized to cause edge effects resulting in vegetation (young trees and shrubs, grasses and herbs) that is attractive to ungulates and bears (*Ursus* spp.) which may then be killed on the road (Ministry of Environment Lands and Parks Parks Division, 2001). Vegetation that is cleared or mowed regularly, either immediately along the road sides or in the median, has a similar attraction to these species groups. On the other hand, some types of mowing practices are believed to temporarily reduce the attractiveness of right-of-way vegetation (e.g. mowing huckleberry (*Vaccinium* spp.) before the berries ripen) (Personal comment Wayne van Velzen, MRPP). Road salt and the relatively early greening of a zone adjacent to the road (south facing slopes and zones that are snow plowed) are other attractants, particularly to ungulates, while road-killed ungulates draw carnivores such as bears to the road (Ministry of Environment Lands and Parks Parks Division, 2001). Hwy 16 also cuts through the limited winter range for deer (*Odocoileus* spp.) and Elk (*Cervus canadensis*) in MRPP between kilometer markers 1-9 and 68-76, and the plowed road and railroad provide an easy travel corridor for large mammals in winter. The number of recorded road killed large mammals in MRPP was 28.8 per year, and estimated at 105 per year (averages 1988-1994) after correcting for likely underreporting (Ministry of Environment Lands and Parks Parks Division, 2001). For the railroad an average of 1.7 large mammals were recorded per year for this same period, but wildlife mortality data for the railroad are believed to be very incomplete (Ministry of Environment Lands and Parks Parks Division, 2001). The species and species groups most frequently reported were moose (*Alces alces*), deer, bear, and elk. Non-native plant species in the disturbed right-of-way along the road and railroad are also considered a problem. Strategies to reduce wildlife-vehicle collisions include modification of mowing or brushing practices in the right-of-way to reduce the attractiveness of the right-of-way vegetation to wildlife, the installation of deer reflectors at two road sections, and increasing the attractiveness of vegetation to wildlife in areas away from the road (Personal comment Wayne van Velzen, MRPP). Some of these strategies conflict with providing wildlife viewing opportunities for the public along Hwy 16.

1.4 Objectives

This project focuses on providing a strategy for the potential future implementation of mitigation measures for wildlife along the transportation corridor. The general objectives of the mitigation measures are to:

- Reduce direct wildlife mortality of medium and large carnivore species on Hwy 16 and the railroad through JNP and MRPP.
- Maintain or improve habitat connectivity for wildlife, specifically medium and large carnivore species, across Hwy 16 and the railroad through JNP and MRPP.

The specific objectives for this project are:

1. Obtain existing wildlife road and railroad mortality and movement data as well as knowledge and experience from local experts for Hwy 16 and the railroad through JNP and MRPP.
2. Analyze the data mentioned above to identify high mortality and movement areas for selected carnivore species and woodland caribou.
3. Discuss the implication of the transportation mortality for the carnivore and caribou populations based on existing data and expert opinion, and prioritize locations based on this analysis.
4. Identify suitable mitigation measures and provide cost estimates for the implementation of these mitigation measures.
5. Review existing wildlife mortality and carnivore movement monitoring programs and provide recommendations for potential improvements, including for the evaluation of the effectiveness of potential future mitigation measures.

2. GENERAL APPROACH AND DATABASE DESCRIPTIONS

The researchers used existing wildlife road and railroad mortality data 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 and robust mitigation measures (see Chapter 1) and form an important part of this highway mitigation plan (see Chapter 7). Because of the relatively long projected life span of these mitigation measures (fences 25 years; underpasses and overpasses 75 years) (Huijser et al., 2009), 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. Other examples are fluctuations in population size as a result of direct competition between two or more species and higher or lower predation pressure on certain species (e.g. changes in wolf (*Canis lupus*) population size and associated changes in predation pressure for ungulates such as elk). These changes are likely to influence the location and number of wildlife-vehicle collisions, and also the species involved. Therefore, the identification of road or railroad sections that may require mitigation should preferably be based on data covering a relatively long time period.

2.1 Databases for Road and Railroad Mortality JNP and MRPP

Wildlife mortality data for Hwy 16 and the railroad in JNP and MRPP are managed by different organizations, the data bases span different time periods, and have different characteristics. The databases are discussed in the following sections:

2.1.1 Hwy 16 through JNP

There is one database for Hwy 16 through JNP: Parks Canada (August 1951 through December 2009). Hwy 16 through JNP is part of the park and park personnel (federal government) are responsible for the maintenance of the road, and set the posted speed limit and potential reductions in posted speed limit. When a dead animal is reported along Hwy 16 in JNP, park wardens almost always pick up the dead animal, conduct a necropsy, and enter the data in a database. For road-killed animals the gender and age are recorded, if possible. Between park personnel (highway maintenance and conservation personnel), the local community, and the visiting public there is at least one check a day along the entire length of Hwy 16 through JNP. Drivers of large trucks that hit animals are suspected to not report such incidents as frequently as drivers of passenger cars, presumably because large trucks are less likely to suffer substantial damage and because of the potential for time loss involved with reporting and possible accident investigation. Nonetheless, other drivers or park personnel typically report carcasses soon after an accident has occurred which then leads to carcass removal and recording of the data. The road mortality data are part of a larger database: the Occurrence Tracking System (OTS). The following parameters are typically recorded for wildlife road mortalities:

- Observation date;
- Species;
- Number of animals killed in an incident;

- Cause of death (“highway”, if known vehicle type (car, semi) is also recorded);
- Road name (e.g. Hwy 16, Hwy 93, though this is often left blank);
- UTM coordinates for the location of the dead animal. The location is not necessarily on or adjacent to the road on which the animal was hit as wounded animals may wander off before they die. Furthermore, the coordinates are more precise since GPS devices were introduced, and the road kilometer system was probably used before the 1980s rather than UTM coordinates which were only added later to the database.
- Notes (all types of information including cause of death, gender and age of the individual animals concerned, location notes, carcass removal notes); and
- Different combinations of gender and age categories.

The OTS is a relatively large database but not all data may be available for analyses. For example, data that relate to current legal cases, including some wildlife-vehicle collisions, cannot be retrieved from the system. This number is thought to be relatively minimal though, but it is likely skewed towards relatively recent incidents.

Ungulates, especially elk and white-tailed and mule deer, are the most frequently recorded species hit by vehicles along the roads in JNP (Figure 2). Coyote is the most frequently recorded carnivore. “Other” represents many different species, all representing less than 5% of the total number of observations. The numbers and percentages of these species are listed in Appendix A.

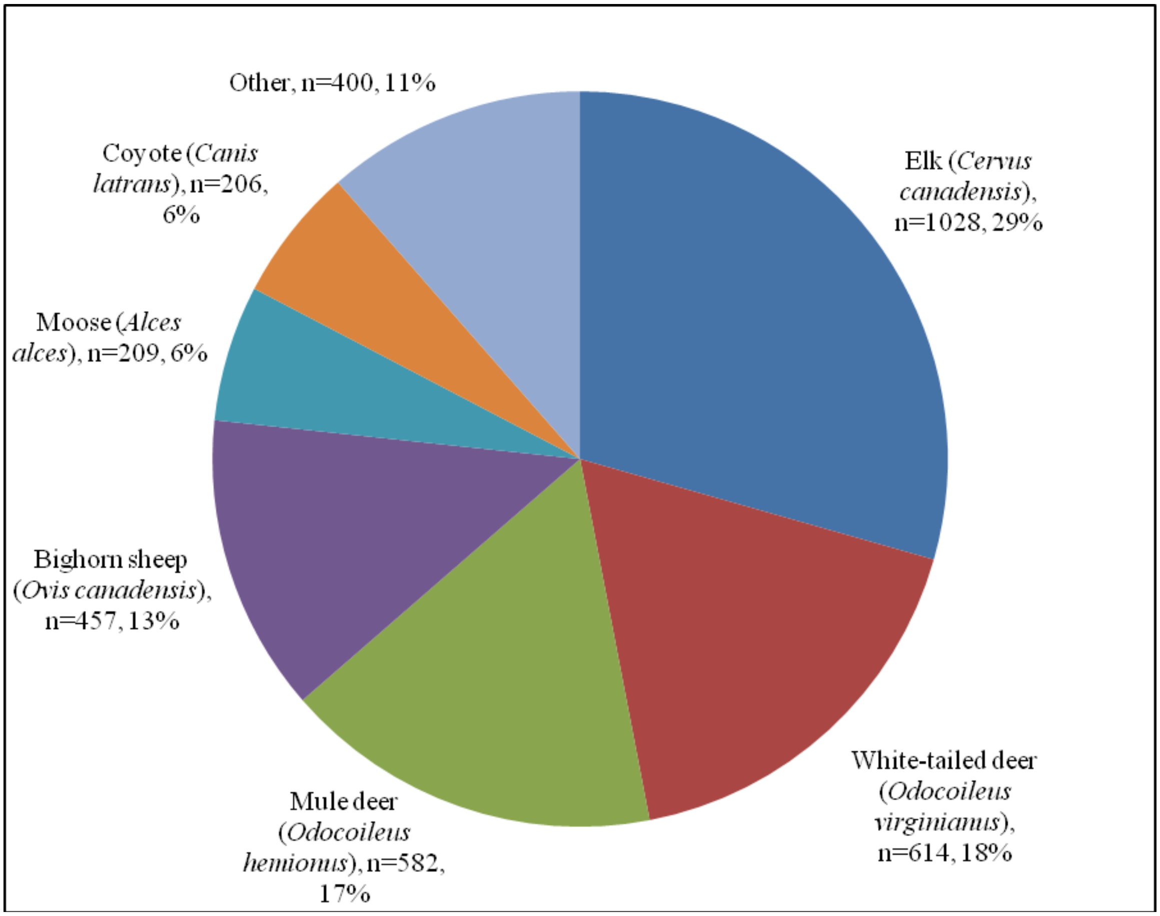

Figure 2. Relative abundance of reported road killed species on all roads in Jasper National Park (August 1951 through December 2009) (N total = 3,496).

2.1.2 Hwy 16 through MRPP

There are two databases for Hwy 16 through MRPP: British Columbia Ministry of Transportation and Infrastructure (January 1998 through December 2009) and the database maintained by Royal Canadian Mounted Police. The latter database contains recorded accidents, including some of the wildlife-vehicle collisions that occur. However, this database was not available to the researchers and was not used for this project. Instead the researchers relied on that database maintained by the British Columbia Ministry of Transportation and Infrastructure that contains carcass removal data. Hwy 16 through MRPP is not part of MRPP and is managed by the British Columbia Ministry of Transportation and Infrastructure. The animal carcasses on and alongside the highway are removed by contractors for the British Columbia Ministry of Transportation and Infrastructure who record the event. The data on the road-killed animals are managed by the British Columbia Ministry of Transportation and Infrastructure. The following parameters are typically recorded for the carcasses:

- Observation year and month (but not day);
- Species;

- Number of individual animals involved;
- Gender and age parameters of the individual animals;
- Region (Hwy 16 through MRPP is region 3);
- District (Hwy 16 through MRPP is district 9);
- Road segment (based on the Landmark Kilometre Inventory (LKI) Segment system (Hwy 16 through MRPP is road segment 1590));
- Hwy number or name;
- Name of nearby town;
- Location on road (measured in kilometers based on the Landmark Kilometre Inventory (LKI) Segment system that identifies landmarks such as bridges, junctions or side roads, pull outs, weigh scales, gates, and border signs); and
- Comment (mostly location description based on land marks).

The location description of the carcasses is not based on a coordinate system, and while the notation is in "kilometers" (often apparently noted to the tenth of a kilometer), the locations are suspected to be artificially concentrated around landmarks that have a known "kilometer value" because that is easier to note for the observers than locations that are further away from such land marks. The data suggest that some observations are accurate to the nearest kilometer, while others appear accurate to one hundred meters or even to ten meters. Kilometer signs occur about every five kilometers, but these signs are not used for the description of the location of the carcasses, and there are no coordinates available for these kilometer signs.

Ungulates, especially moose and deer, are the most frequently recorded species hit by vehicles along the roads in MRPP (Figure 3). Bear species are the most frequently recorded carnivores. "Other" represents many different species, all representing less than 5% of the total number of observations. The numbers and percentages of these species are listed in Appendix A.

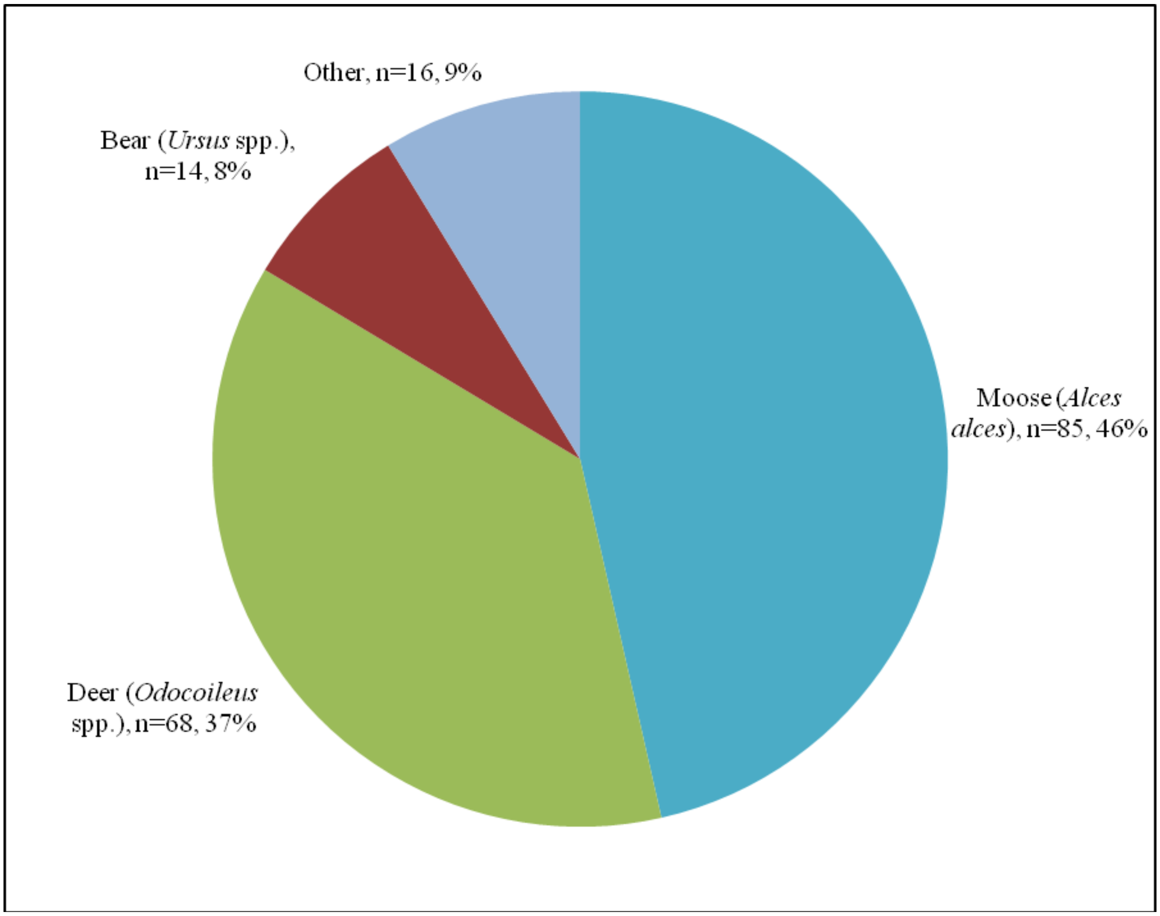

Figure 3. Relative abundance of reported road killed species along Hwy 16 in Mount Robson Provincial Park (January 1998 through December 2009) (N total = 183).

2.1.3 Railroad through JNP

There are two databases for wildlife mortality along the railroad through JNP. One is maintained by Parks Canada (October 1952 through December 2009) and the other by Canadian National Railway Company (November 1997 through October 2010). Since the database maintained by Parks Canada was likely more complete, the researchers only used this database for the current project. The Parks Canada database contains data collected from different sources: 1. Data collected by the Canadian National Railway Company (identical to the database that was not used) and 2. Data collected from other sources including park personnel and the public. For a description of the database from the Canadian National Railway Company see next point (railroad through MRPP). Data collected by park wardens and the public are likely to be more frequent near towns and where roads are close to or cross the railroad. These railroad mortality data are part of a larger database: the Occurrence Tracking System (OTS). The parameters typically recorded have already been described above under the point above "Hwy 16 through JNP". The data from the Canadian National Railway Company have been assigned coordinates for the location of the incidents.

Ungulates, especially elk and bighorn sheep, are the most frequently recorded species hit by trains in JNP (Figure 4). Black bear is the most frequently recorded carnivore. “Other” represents many different species, all representing less than 5% of the total number of observations. The numbers and percentages of these species are listed in Appendix A.

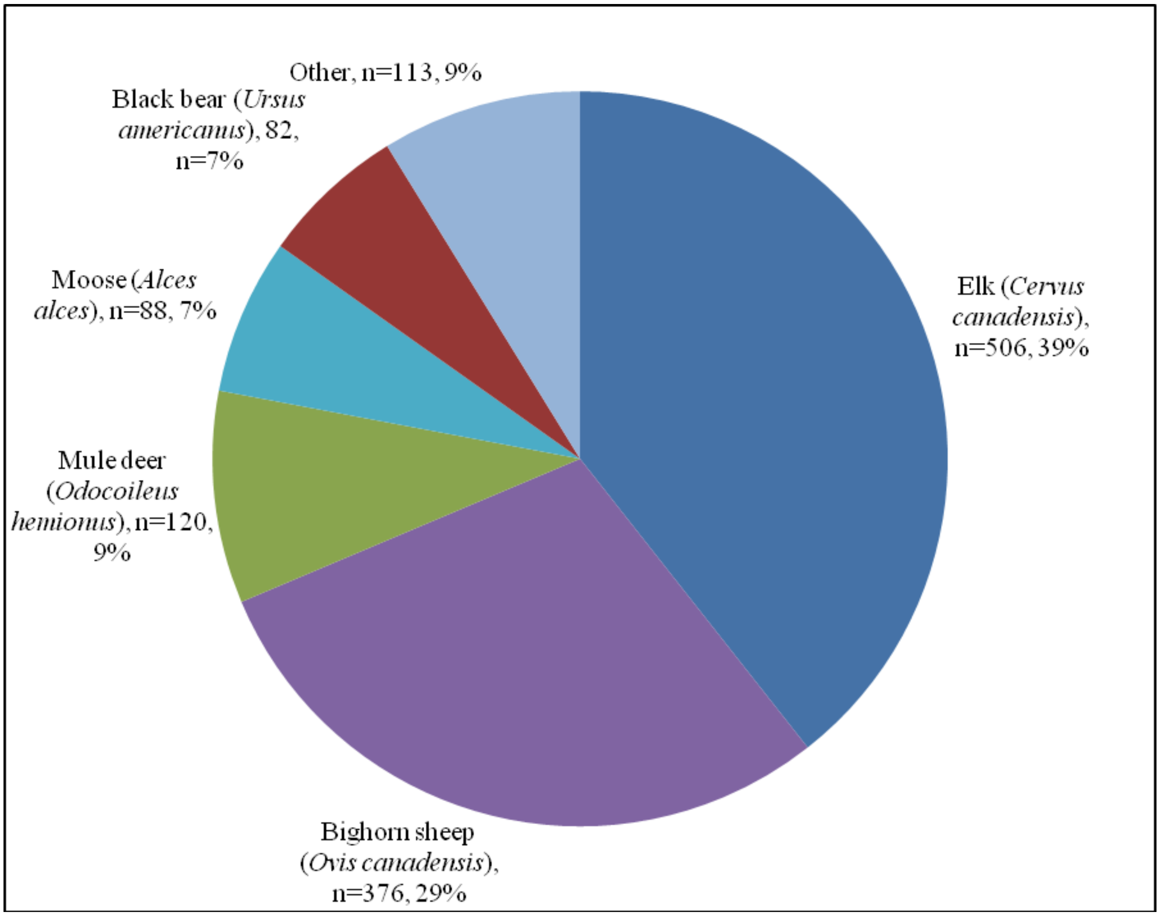

Figure 4. Relative abundance of reported railroad killed species in Jasper National Park (October 1952 through December 2009) (N total = 1,285).

2.1.4 Railroad through MRPP

There is one database for the railroad through MRPP: Canadian National Railway Company (November 1997 through October 2010). Data on animals hit by trains through MRPP are collected and managed by Canadian National Railway Company. The records are based on reports from train drivers having hit large animals. The following parameters are typically recorded for the carcasses:

- Observation date;
- Species;

- Killed/injured (whether the animal involved was killed or injured);
- Subsection; and
- Railroad mile marker (typically to tenth of mile).
- The railroad markers (1.0 mile apart) have coordinates available for them, allowing the researchers to interpolate and estimate the coordinates for the tenth of a mile mark locations in between the one mile markers.

Ungulates, especially moose and deer, are the most frequently recorded species hit by trains in MRPP (Figure 5). Black bear is the most frequently recorded carnivore. The numbers and percentages of these species are also listed in Appendix A to be consistent with the other databases.

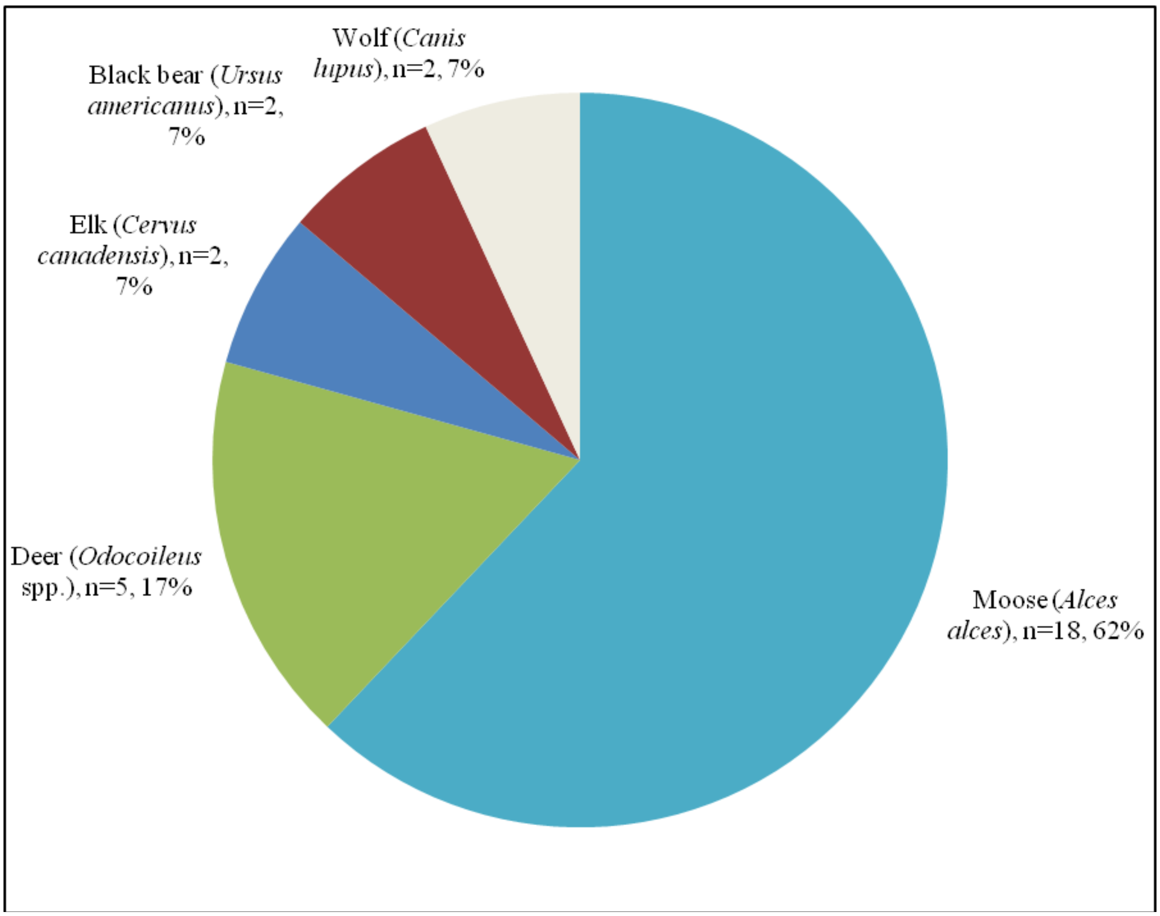

Figure 5. Relative abundance of reported railroad killed species in Mount Robson Provincial Park (November 1997 through October 2010) (N total = 29).

The different databases not only covered different time periods, but they were also based on different search and reporting efforts as described above. For this reason the researchers distinguished between the road and railroad and also between JNP and MRPP. This resulted in four road or railroad segments:

- Hwy 16 through JNP (77.43 km)
- Hwy 16 through MRPP (62.81 km)
- Railroad through JNP (77.41 km)
- Railroad through MRPP (76.37 km (59.53 km for Albreda section and 16.84 km for Robson section which branches off on the west side of MRPP))

Since there were no coordinates for the Hwy 16 and railroad mortality observations in MRPP, the researchers had to plot the data based at coordinates of the start and end point of road segments along Hwy 16 (based on the Landmark Kilometre Inventory (LKI) system) and the coordinates for the mile marker posts along the railroad. Therefore the location of the Hwy 16 road mortalities and the railroad mortalities in MRPP were always precisely on Hwy 16 or the railroad.

2.2 Other Databases Used

For some of the analyses the researchers also used live animal observations (see section 2.4 for a rationale). However, such observations were only available for JNP and not for MRPP. The observations for live animals were retrieved from the same database as the road and railroad mortalities for JNP: the Occurrence Tracking System (OTS).

2.3 Time Periods Included for Identification and Prioritization Process

The researchers based the identification of road or railroad sections in JNP that may require mitigation on all mortality data available from the database from Parks Canada (August 1951 through December 2009 for road mortalities and October 1952 through December 2009 for railroad mortalities). The data spanned approximately 58 years and 57 years respectively. 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. Therefore the prioritization of road sections that require mitigation is essential. The prioritization of the road sections in JNP is based on wildlife road and railroad mortality data covering a much shorter time period, ten years (January 2000 through December 2009), than the data used to identify these road sections. This means that the available funds are first invested at locations that have shown the most road mortality over the last decade, 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.

For MRPP the researchers based the identification of road or railroad sections that may require mitigation on all mortality data available from the database from British Columbia Ministry of

Transportation and Infrastructure for Hwy 16 (January 1998 through December 2009) and on all mortality data available from the database from Canadian National Railway Company for the railroad (November 1997 through October 2010). Since the road and railroad mortality data only covered 13 and 14 years respectively the researchers did not use a subset of the data to prioritize road or railroad sections that require mitigation. Instead the identification and prioritization was all based on the same data covering 13 years for Hwy 16 and 14 years for the railroad.

The researchers recognize that there are likely to be changes in the search and reporting effort over the years. However, such changes do not necessarily influence the process used to identify or prioritize road or railroad sections that may require mitigation. It is only when wildlife road or railroad 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 and railroad 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 for animal mortalities was more or less similar within the four road and railroad sections listed above. There is a possibility though that the railroad data in JNP are influenced by higher search and reporting effort near towns and where roads are close to the railway or where roads cross the railway.

2.4 Species and Types of Observations Included for Identification and Prioritization Process and Recommendations

If safe crossing opportunity locations are based on where species are most often hit then locations where animals cross the road successfully (i.e. without getting hit) may not be mitigated, or, potentially worse, have fences installed making the road or railroad into an impermeable barrier. Therefore it is important to include not only mortality observations but also live observations when making a decision on the type and location of potential mitigation measures.

Consistent with project objectives, site identification and prioritization will is based on the focal species. After consultation with John Wilmshurst (Ecosystem Science Coordinator, Jasper National Park, Parks Canada) the species list for carnivores was further defined and woodland caribou (*Rangifer tarandus caribou*) was added to the list of focal species because of the special concerns about its conservation status in the area and its formal designation as a species at risk (Table 1). For analyses that aimed to identify locations for safe crossing opportunities mortality and live observations of large ungulate species (“selected other species”) (Table 1) were also included to avoid erecting barriers where these have been observed on or near the road.

Table 1. The focal species of this report consisting of selected carnivore species and caribou, and "selected other species" that also influenced decisions on the type and location of potential mitigation measures. Code refers to the code in the OTS database of Parks Canada (see Appendix A).

Focal species **Species name**	**Code**	**Selected other species** **Species name**	**Code**
Fisher (*Martes pennanti*)	FISH	White-tailed deer (*Odocoileus virginianus)*	WHIT, DEER
Wolverine (*Gulo gulo)*	WOLV	Mule deer (*Odocoileus hemionus)*	MULE, DEER
Canada lynx (*Lynx canadensis)*	LYNX	Elk (*Cervus canadensis*)	ELK
Cougar (*Puma concolor)*	COUG	Moose (*Alces alces)*	MOOS
Red fox (*Vulpes vulpes*)	REFO, FOX	Mountain goat (*Oreamnos americanus*)	GOAT
Coyote (*Canis latrans)*	COYO	Bighorn sheep (*Ovis canadensis*)	SHEE
Wolf (*Canis lupus*)	WOLF		
Black bear (*Ursus americanus)*	BLAC, BEAR		
Grizzly bear (*Ursus arctos*)	GRIZ, BEAR		
Woodland caribou (*Rangifer tarandus caribou*)	CARI		

2.5 Spatial Resolution

The spatial resolution of the data presented in this manuscript is assumed to be 100 m. This resolution recognizes imprecision in the wildlife road mortality data (see e.g. Clevenger et al. 2002) and the incidental observations data, especially data recorded prior to GPS use. This also relates to more current data on road and railroad mortalities in MRPP that were recorded on a landmark kilometer system (Hwy 16) or mile marker system (railroad). Nevertheless this resolution is sufficiently precise to inform on the location of potential future mitigation measures.

3. CURRENT WILDLIFE MORTALITY ALONG HWY 16 AND THE RAILROAD

3.1 Mortality in JNP and MRPP

The researchers selected all highway and railway mortality records that related to the focal species and selected other species (see Table 1) for JNP and MRPP. The location of the road and railroad mortalities in MRPP was by definition on Hwy 16 or the railroad (see section 2.1). In JNP however this was not the case for different reasons:

- The location for the road and railroad mortalities in JNP is based on a coordinate system. Depending on the accuracy with which the coordinates were obtained, the location may not be exactly on the road or railroad.
- The location for the road and railroad mortalities in JNP is based on the location of the actual carcass rather than the location of where the animal was originally struck by a car or train. If the animal does not die immediately, the animal may wander far away from the road or railroad before it eventually dies. In some cases park personnel successfully tracks such animals, resulting in locations that may be far from the road or railroad.
- There are other roads in JNP besides Hwy 16 along which road mortalities were recorded. If the incident occurred on another road, then it is very unlikely that the coordinates for the road-killed animal coincide with Hwy 16. There is only one railroad through JNP, so there is no doubt on which railway railroad the mortalities must have occurred.

The researchers used observations from a ten year period (1 January 2000 through 31 December 2009) to calculate the “current” average number of reported road and railroad mortalities per year (Table 2). Data from earlier years may not reflect the “current” mortality rates as wildlife population sizes fluctuate and data from earlier years were likely collected with varying search and reporting effort. On average there were about 24 mortalities reported per year for the focal species, with black bear, coyotes and wolves among the most frequently reported species. Selected other species, all ungulates, were reported more frequently with an average of about 155 mortalities per year. Overall, elk was the most frequently reported species, but white-tailed deer, mule deer, bighorn sheep and moose were also reported relatively often.

The numbers in Table 2 are based on the records in the database and should be considered a minimum estimate for the road and railroad mortalities in JNP and MRPP.

Table 2. The average number of reported road and railroad mortalities per year for the focal species and selected other species (see Table 1) in JNP (all roads and the railroad) and MRPP (Hwy 16 and the railroad). All averages are based on a 10 year period from 1 January 2000 through 31 December 2009 (see Appendix B for the reported mortalities per year). Al. = Albreda section, Ro. = Robson section.

	All roads (incl. Hwy 16)			Railroad				
Species	JNP	MRPP	Total	JNP	MRPP		Total	Total
					Al.	Ro.		
Focal species								
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo)*	0.3	0	0.3	0	0	0	0	0.3
Canada lynx (*Lynx canadensis)*	1.1	0	1.1	0	0	0	0	1.1
Cougar (*Puma concolor)*	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0.8	0	0.8	0.1	0	0	0.1	0.9
Coyote (*Canis latrans)*	7.4	0.2	7.6	0.3	0	0	0.3	7.9
Wolf (*Canis lupus*)	2.9	0.6	3.5	0.9	0.1	0.1	1.1	4.6
Black bear (*Ursus americanus)*	3.5	1.4	4.9	3.7	0.2	0	3.9	8.8
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0
Caribou (*Rangifer tarandus caribou*)	0.4	0	0.4	0	0	0	0	0.4
Sub total	16.4	2.2	18.6	5.0	0.3	0.1	5.4	24.0
Selected other species								
White-tailed deer (*Odocoileus virginianus)*	35.0	0	35.0	2.9	0	0	2.9	37.9
Mule deer (*Odocoileus hemionus)*	19.0	0	19.0	3.8	0	0	3.8	22.8
Deer (*Odocoileus hemionus)*	0	5.5	5.5	0.3	0.3	0	0.6	6.1
Elk (*Cervus canadensis*)	33.8	0.4	34.2	17.6	0	0	17.6	51.8
Moose (*Alces alces)*	5.3	6.2	11.5	2.0	0.6	0.0	2.6	14.1
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	12.3	0	12.3	10.1	0	0	10.1	22.4
Sub total	105.4	12.1	117.5	36.7	0.9	0	37.6	155.1
Total	121.8	14.3	136.1	41.7	1.2	0.1	43.0	179.1
Note: For Hwy 16 in MRRP Bear species was never identified; "Bear" was assumed to be black bear								

3.2 Mortality along Hwy 16 and the Railroad in JNP and MRPP

Here we report on only Hwy 16 and railroad mortalities in JNP and MRPP. Since the location of the road and railroad mortalities in MRPP was by definition on Hwy 16 or the railroad (see section 2.1), there is no difference between the data for MRPP in this section and the previous one (section 3.1). However for the observations in JNP there is a substantial difference as the researchers had to adjust the data selection because of the following issues:

- There are non-Hwy 16 road mortality records in JNP. Therefore the observations that related to roads other than Hwy 16 were omitted. This was only possible though for records that identified the road or highway.
- In cases in which the road was not identified, we set a maximum distance of 500 m (a 1000 m wide zone) from Hwy 16 to include the vast majority of the observations likely to have originated from a collision on Hwy 16 (Figure 6) and to exclude observations that likely occurred on other roads.

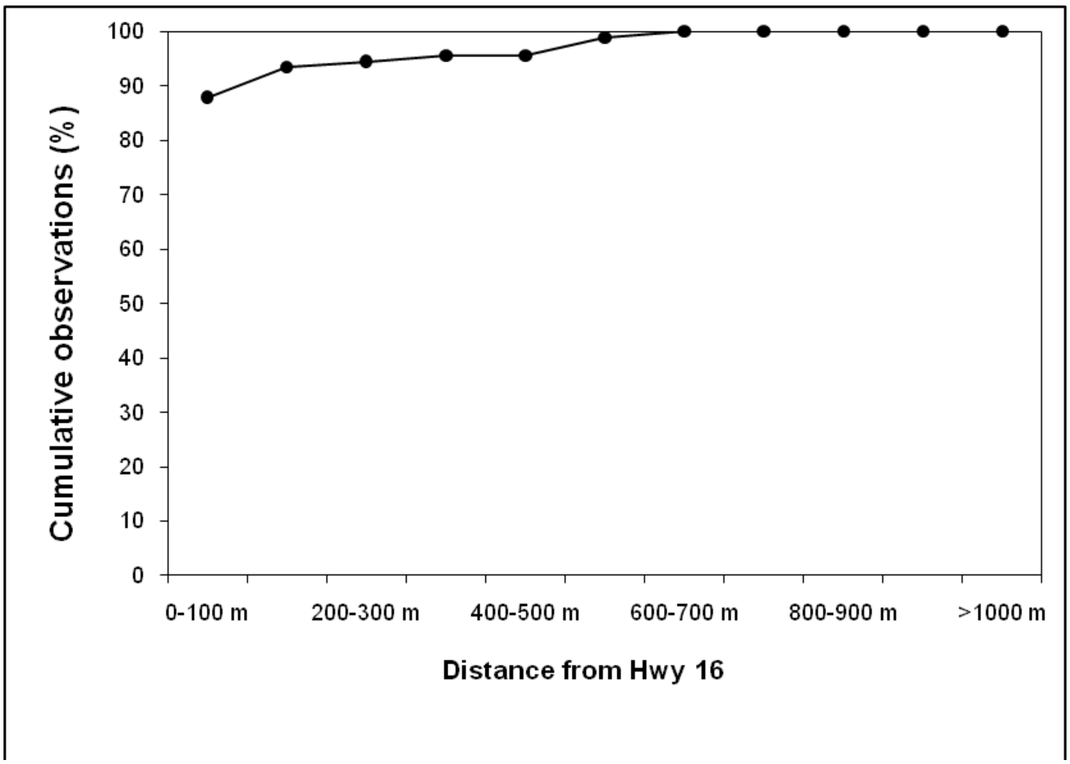

Figure 6. The cumulative percentage of the road mortality observations in JNP originating at Hwy 16 of the focal species at increasing distance from Hwy 16 (n=91). Note that the records selected all related to "Hwy 16" based on the description in the database. Observations that were on or close to Hwy 16 but did not have a road name or number indicated were not included in this graph.

- There are obvious errors in the dataset. The researchers did not correct any of these likely errors as this could not be done without being subjective. The apparent errors relate to location (i.e. it is unlikely that the animal that was killed by a vehicle or train was actually found on the location indicated) or the type of mortality (i.e. it is unlikely that the animal was hit by a vehicle or train when the nearest railroad is at least several dozens of kilometers away) (e.g. Figure 7). For Hwy 16 this problem was limited by setting a maximum distance of 500 m from Hwy 16. For the railroad, the same maximum distance (500 m) was set to exclude likely errors in the data (Figure 8).

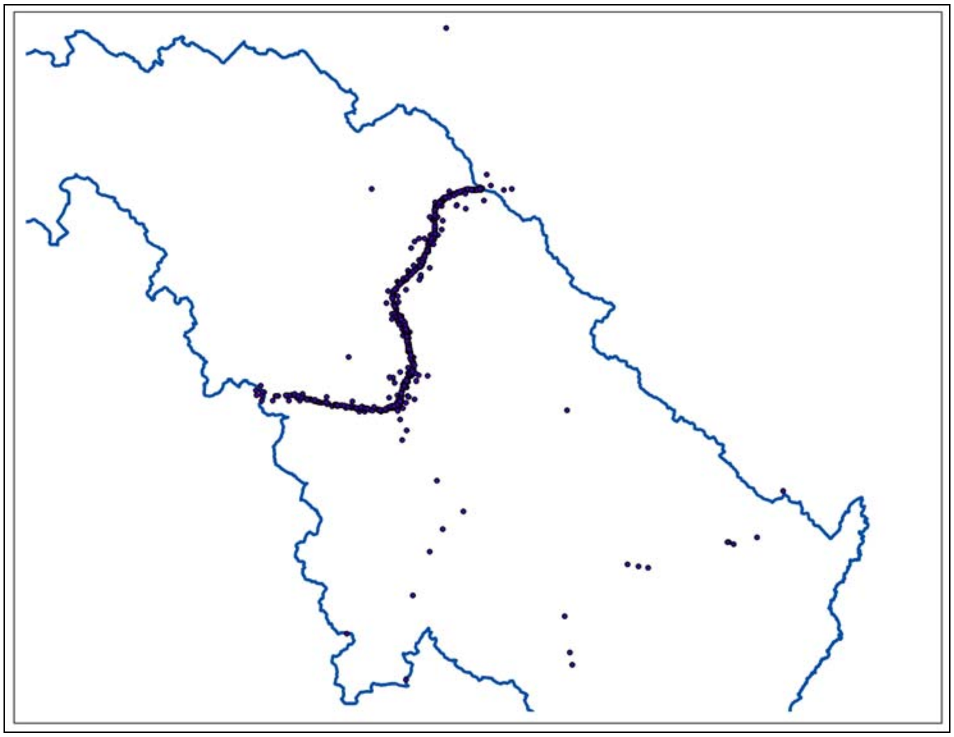

Figure 7. The locations of the railroad mortality observations in JNP (October 1952 through December 2009) (N total = 1,285). This map shows likely errors in the database for records with locations that are far away from the railroad. The route of the railroad is indicated by the line resulting from the points overlapping in the center of the map.

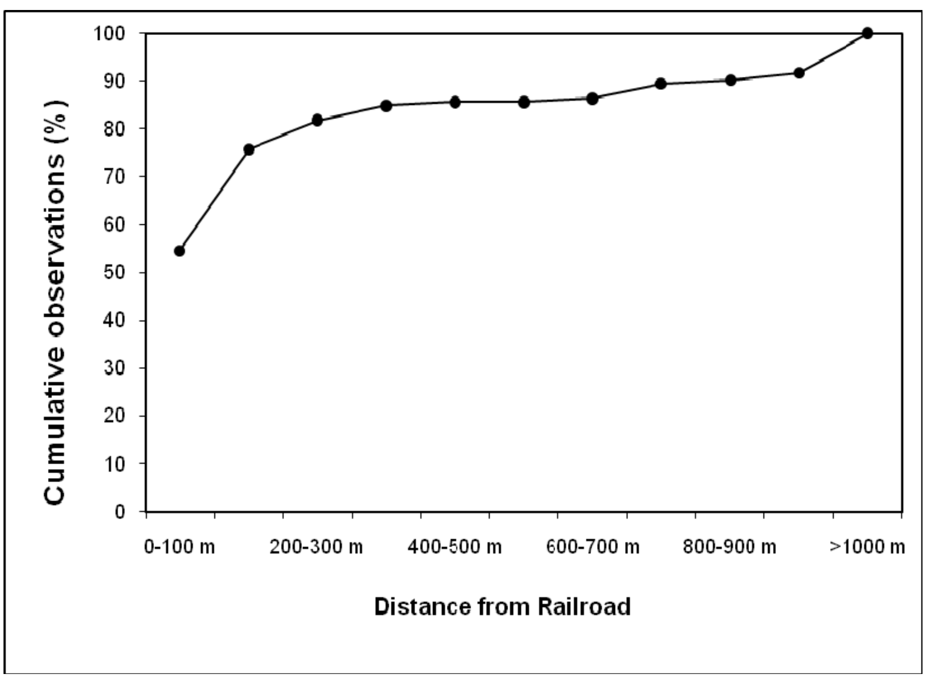

Figure 8. The cumulative percentage of the railroad mortality observations in JNP of the focal species at increasing distance from the railroad (n=130).

This process resulted in a dataset for both Hwy 16 and the railroad in which the individual observations were at the most 500 m away from the road or railroad (Table 3). For JNP 83.9% (annual average 150.3 out of 179.1) of all reported road and railroad mortalities were located within this zone. Black bear, coyote and wolf were the most frequently reported focal species. Overall, elk was the most frequently reported species, but white-tailed deer, mule deer, bighorn sheep and moose were also often reported. The vast majority of the collisions (87%; annual average 95.8 out of 110.1) along Hwy 16 are reported from JNP rather than MRPP. The situation for the railroad is similar with 97% in JNP (annual average 38.9 out of 40.2). There are indications of differences in habitat and species composition between JNP and MRPP with more moose in MRPP and fewer deer, elk, and bighorn sheep. However, there are also likely differences in search and reporting effort between JNP and MRPP.

The numbers in Table 3 are based on the records in the database and should be considered a minimum estimate for the road and railroad mortalities along Hwy 16 and the railroad in JNP and MRPP. Estimates on how many animals may be hit but whose carcasses are never found or reported vary substantially. In Virginia, United States, the number of animal carcasses that were eventually recorded in the carcass removal database was only 13.3% (99 out of 743) of the actual number of carcasses removed along roads by road maintenance crews (Donaldson & Lafon, 2008). For a road in north western Montana, road maintenance crew personnel estimated that of all large mammal carcasses observed along the road only about 80% are removed and reported (Huijser et al., 2006a). Another 30-40% of the deer carcasses are estimated to be removed by others, either legally or illegally. In British Columbia, the number of animals recorded in the database of the Ministry of British Columbia Ministry of Transportation and Infrastructure is estimated to be only 25% of the actual number of animals killed on the roads (Sielecki 2004). However, this estimate is based on animals of all sizes. Hesse (2006) states that the animal carcass reporting system in British Columbia may only report 25% of all carcasses for large mammals.

One may argue that the search and reporting effort along Hwy 16 through JNP is relatively frequent and thorough because:

- Hwy 16 is part of JNP, is maintained by Parks Canada, and the park has natural resource management personnel and road maintenance personnel travel the road frequently.
- Natural resource management and visitor experience (dead animals along the road are typically considered “unsightly”) are among the core tasks for JNP personnel.
- Observations by Parks Canada personnel are supplemented by observations from the public who also tend to drive the highway with a relatively great sense of awareness about the natural resources and potential problems with wildlife and negative impacts on landscape aesthetics and visitor experience.

The search and reporting effort along Hwy 16 in MRPP and the railroad in JNP and MRPP is likely substantially lower than along Hwy 16 in JNP. However, based on direction provided by the steering committee for this project the researchers did not apply correction factors to obtain more realistic mortality estimates.

Table 3. The average number of reported road and railroad mortalities per year for the focal species and selected other species (see Table 1) along Hwy 16 and the railroad in JNP and MRPP. The mortalities from JNP include observations up to 500 m (1000 m wide zone) from the road or railroad. All averages are based on a 10 year period from 1 January 2000 through 31 December 2009 (see Appendix C for the reported mortalities per year). Al. = Albreda section, Ro. = Robson section.

	Hwy 16			Railroad				
Species	JNP	MRPP	Total	JNP	MRPP		Total	Total
					Al.	Ro.		
Focal species								
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo)*	0.2	0	0.2	0	0	0	0	0.2
Canada lynx (*Lynx canadensis)*	0.8	0	0.8	0	0	0	0	0.8
Cougar (*Puma concolor)*	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0.5	0	0.5	0.1	0	0	0.1	0.6
Coyote (*Canis latrans)*	5.9	0.2	6.1	0.3	0	0	0.3	6.4
Wolf (*Canis lupus*)	2.4	0.6	3.0	0.9	0.1	0.1	1.1	4.1
Black bear (*Ursus americanus)*	2.4	1.4	3.8	3.3	0.2	0	3.5	7.3
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0
Caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0
Sub total	*12.2*	*2.2*	*14.4*	*4.6*	*0.3*	*0.1*	*5.0*	*19.4*
Selected other species								
White-tailed deer (*Odocoileus virginianus)*	26.0	0	26.0	2.7	0	0	2.7	28.7
Mule deer (*Odocoileus hemionus)*	13.5		13.5	3.6	0	0	3.6	17.1
Deer (*Odocoileus hemionus)*	0.8	5.5	6.3	0.3	0.3	0	0.6	6.9
Elk (*Cervus canadensis*)	27.6	0.4	28.0	15.9	0	0	15.9	43.9
Moose (*Alces alces)*	4.4	6.2	10.6	1.9	0.6	0	2.5	13.1
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	11.3	0	11.3	9.9	0	0	9.9	21.2
Sub total	*83.6*	*12.1*	*95.7*	*34.3*	*0.9*	*0*	*35.2*	*130.9*
Total	95.8	14.3	110.1	38.9	1.2	0.1	40.2	150.3
Note: For Hwy 16 in MRRP Bear species was never identified; "Bear" was assumed to be black bear								

4. IDENTIFICATION AND PRIORITIZATION OF WILDLIFE MORTALITY SECTIONS

4.1 Data Selection and Projection onto Hwy 16 and Railroad for Identification Mortality Sections

The researchers used a two-step process to select road and railroad mortality data and project them onto Hwy 16 and the railroad:

1. All records from all years that related to the focal species (Table 1) were selected. All available data from all years were used to incorporate, at least to a certain extent, the dynamics of the ecosystem with regard to the species hit and the locations they were hit over a time period consistent with the lifespan (e.g. 75 years for concrete structures) of potential mitigation measures.
2. In JNP the researchers had to address the issues listed in section 3.2 and project the locations of the road and railroad mortalities onto Hwy 16 and the railroad. Only observations that were located within 200 m from Hwy 16 and the railroad (400 m wide zones) were included as spatial errors with regard to the location of the collision increase with the distance of the observation to the road or railroad. For the focal species 93.4% (85 observations (85 records) out of 91 observations (91 records)) of the observations that originated on Hwy 16 (according to the database) were within 200 m from Hwy 16 (Figure 6). For the railroad this was 75.8% (100 observations (98 records) out of 132 observations (130 records)) (Figure 8). The location of the road and railroad mortalities in MRPP was by definition on Hwy 16 or the railroad (see section 2.1). Therefore the data from MRPP did not have to be projected onto the road or railroad.

4.2 Species Hit and Located up to 200 m Away from Hwy 16 or Railroad

There is an interesting difference in species mortality composition between the road and the railroad in JNP that have similar length and had a similar monitoring period. Grizzly bears appear to be hit much more often on the railroad than on Hwy 16 in JNP. When considering the search and reporting effort (see section 3.2) that is likely to be lower along the railroad than Hwy 16, black bears may also be hit more frequently along the railroad than along Hwy 16. Note that only the focal species are listed in Table 4, and that there are many more species reported to have been hit along Hwy 16 and the railroad through JNP and MRPP. Species smaller than deer were ignored by the researchers for this comparison as they may be much harder to notice for train drivers or anyone picking up and recording animal carcasses along roads or railroads.

Table 4. The number of recorded road and railroad mortalities of the focal species (see Table 1) within 200 m (i.e. a 400 m wide zone with road or railroad in the middle) from Hwy 16 or the railroad through JNP and MRPP. Note that the numbers are based on monitoring periods of different duration. Time periods: Road mortality JNP: August 1951 through December 2009; Road mortality MRPP: January 1998 through December 2009; Railroad mortality JNP: October 1952 through December 2009; Railroad mortality MRPP: January 1998 through December 2009.

	Hwy 16		Railroad		
Species	JNP	MRPP	JNP	MRPP	
				Albreda	Robson
Fisher (*Martes pennanti*)	0	0	0	0	0
Wolverine (*Gulo gulo)*	3	0	2	0	0
Canada lynx (*Lynx canadensis)*	10	0	0	0	0
Cougar (*Puma concolor)*	1	0	0	0	0
Red fox (*Vulpes vulpes*)	11	0	1	0	0
Coyote (*Canis latrans)*	152	2	2	0	0
Wolf (*Canis lupus*)	57	6	19	1	1
Black bear (*Ursus americanus)*	67	14*	64	2	0
Grizzly bear (*Ursus arctos*)	3	0	12	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0
Total	304	22	100	3	1

* Bear species was never identified in the database; every "bear" was assumed to be a black bear

4.3 Mortality Clusters Focal Species

Hwy 16 and the railroad in JNP and MRPP were divided into 100 m long units (see Appendix D Topographic maps with 100 m units). The researchers distinguished five different road and railroad sections that each had their own numbering system for these 100 m long road units:

- Hwy 16 through JNP (77.43 km in length): start (0.0 km point) coincides with the east gate of JNP; end (77.43 km point) coincides with the boundary between JNP and MRPP.
- Hwy 16 through MRPP (62.81 km in length): start (0.0 km point) coincides with the boundary between JNP and MRPP; end (62.81 km point) coincides with the west entrance to MRPP.
- Railroad through JNP (77.41 km): start (0.0 km point) coincides with the eastern border of JNP; end (77.41 km point) coincides with the boundary between JNP and MRPP.
- Railroad through MRPP Albreda section (59.53 km in length): start (0.0 km point) coincides with the boundary between JNP and MRPP; end (59.53 km point) coincides

with the west entrance to MRPP. Total length of the railroad through MRPP is 76.37 km (Albreda and Robson section combined).

- Railroad through MRPP Robson section (16.84 km in length): start (0.0 km point) coincides with the junction with the Albreda section at Red Pass; end (16.84 km point) coincides with the west entrance to MRPP. Total length of the railroad through MRPP is 76.37 km (Albreda and Robson section combined).

All selected wildlife road and railroad mortality observations (see section 4.1 and 4.2) for the focal species were projected to the nearest 100 m road unit using a GIS (ESRI ArcGIS 9.2) and summed (Appendix E). Road and railroad sections with a concentration of wildlife mortality were identified separately for the road and railroad sections through JNP and MRPP because the researchers estimated the search and reporting effort to vary greatly between these sections. However, the Albreda and Robson section of the railroad through MRPP were combined as the researchers estimated the search and reporting effort for these sections to be similar.

The procedure for the road and railroad sections through JNP and MRPP was as follows:

- All focal species (see Table 1) were weighted equally. The number of observations in each 100 m long unit is equivalent to the total number of wildlife mortality observations, regardless of the species, in or adjacent (maximum distance from road or railroad is 200 m).
- To account for mortalities that occur in one unit but are observed in an adjacent unit, a "focal species mortality value" was calculated by summing mortalities the unit concerned and its two neighboring units (Appendix E). Thus the "focal species mortality value" for each 100 m unit was related to a 300 m long moving window of observations.
- Six percentile categories (absent (0%), very low (>0-<20%), low (20-<40%), medium (40-<60%), high (60-<80%), and very high (80-100%) (Table 5) of the "focal species mortality values" were distinguished for the 100 m units.

Table 5. Cutoff levels of "focal species mortality values" for the road and railroad sections through JNP and MRPP.

Infrastructure Sections	Absent	Very low	Low	Medium	High	Very high
Hwy 16 JNP	0	1	1	1	2	3-11
Hwy 16 MRPP	0	1	1	1	1	2-3
Railroad JNP	0	1	1	1	1	2-6
Railroad MRPP	0	1	1	1	1	1

To identify mortality clusters all 100 m segments classified as "very high" were marked (Appendix E). In addition, "high" segments were marked as well if they were adjacent to a very high segment (Appendix E). Thus, "focal species mortality clusters" consisted of the "worst 20%" of all 100 m units (excluding the 100 m 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 units that were classified as “absent”) (Appendix E).

The following data were available:

- Hwy 16 through JNP: August 1951 through December 2009.
- Hwy 16 through MRPP: January 1998 through December 2009.
- Railroad through JNP: October 1952 through December 2009.
- Railroad through MRPP: November 1997 through October 2010.

The mortality values in Table 6 are relatively low, especially for Hwy 16 and the railroad through MRPP. Due to the short time period that data were available for in MRPP and the relative rarity of the focal species. Because of this, we found no or very little distinction among some of the categories listed in Table 5. A difference of just one observation can result in categorizing a 100 m unit as a mortality cluster or not. This affected the robustness of the identification of the mortality clusters for the focal species.

4.4 Buffer Zones, Gaps, and Mitigation Zones

For each focal species mortality cluster in JNP and MRPP, the researchers presented the raw data in Appendix E. This allows for informed decisions on whether to indeed implement mitigation measures for a mortality cluster and what species the mitigation measures should be designed for.

If wildlife road or railroad mortality in the mortality clusters for focal species is reduced through the installation of e.g. wildlife fencing, wildlife that wants to cross the road or railroad or that is attracted to the right-of-way vegetation may still gain access to the road, railroad or right-of-way 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 from crossing the road or railroad or accessing the right-of-way vegetation should have buffer zones that extend beyond the location of the mortality clusters. For this project the buffer zone was set at 1 km.

The researchers did not apply a minimum size for a gap of the mitigation measures; the buffer zones of adjacent mortality clusters either connect or have a gap size of 100 m or greater. However, when a decision is made on the implementation of mitigation measures, one may choose to set a minimum gap size in between the buffer zones. For example, it makes little sense to apply buffer zones of 1 km and allow for a 100 m gap in between buffer zones. The researchers suggest a minimum gap size of 1 km when applying 1 km long buffer zones. The mortality clusters for the focal species and the 1 km buffer zones are shown in Figures 9-12. The mortality clusters and buffer zones combined form the mitigation zones.

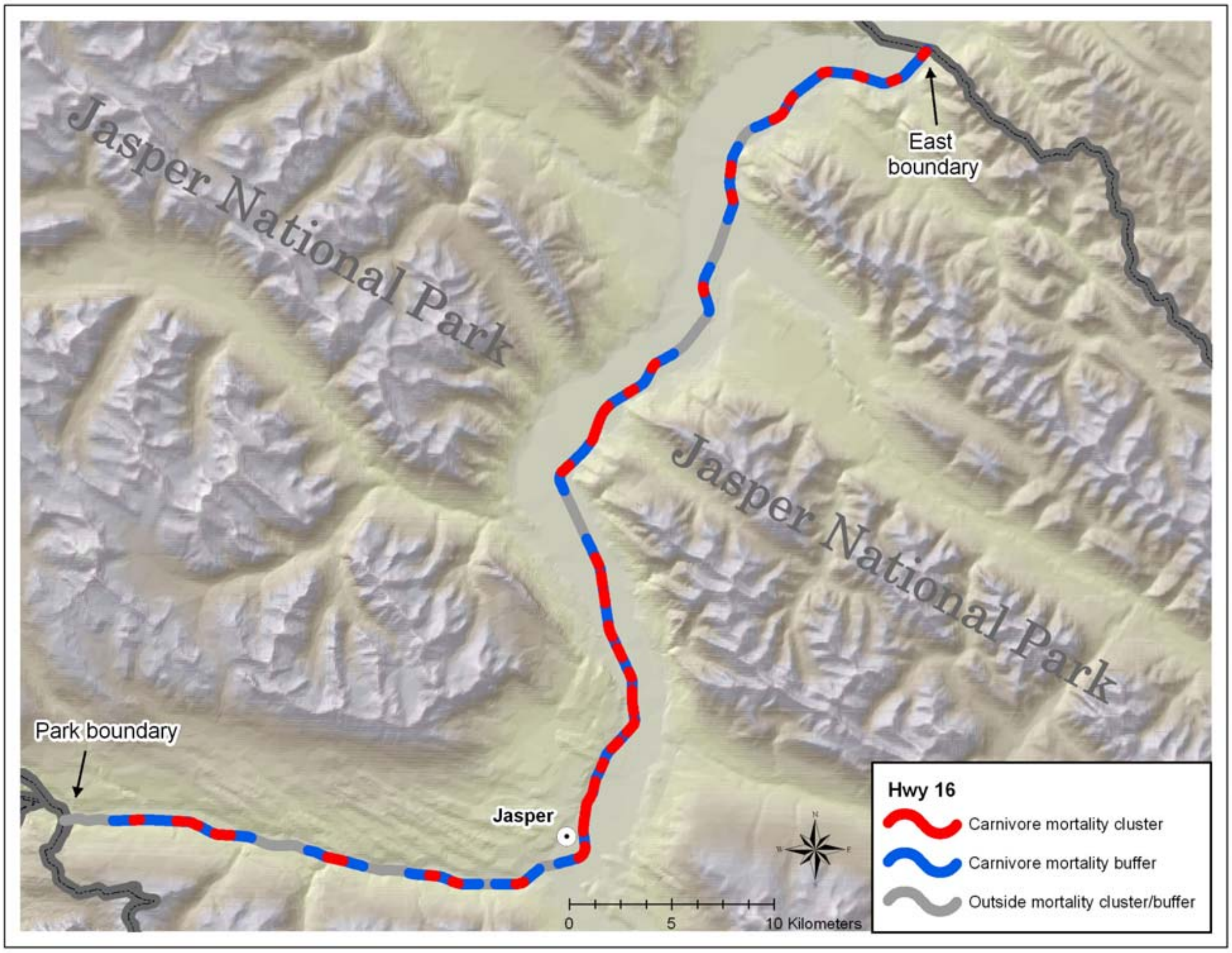

Figure 9. The mortality clusters for the focal species and associated 1 km long buffer zones for Hwy 16 through JNP.

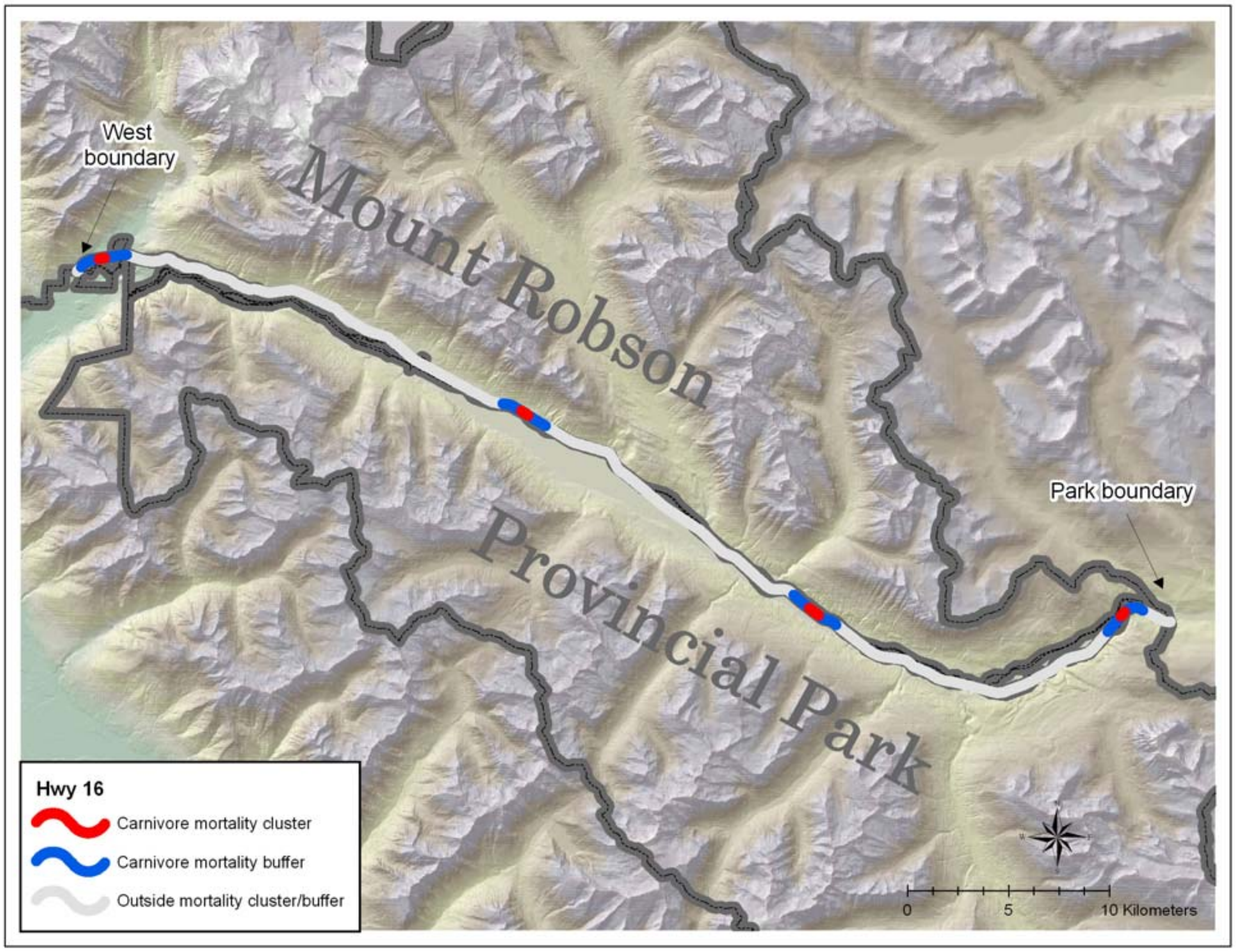

Figure 10. The mortality clusters for the focal species and associated 1 km long buffer zones for Hwy 16 through MRPP.

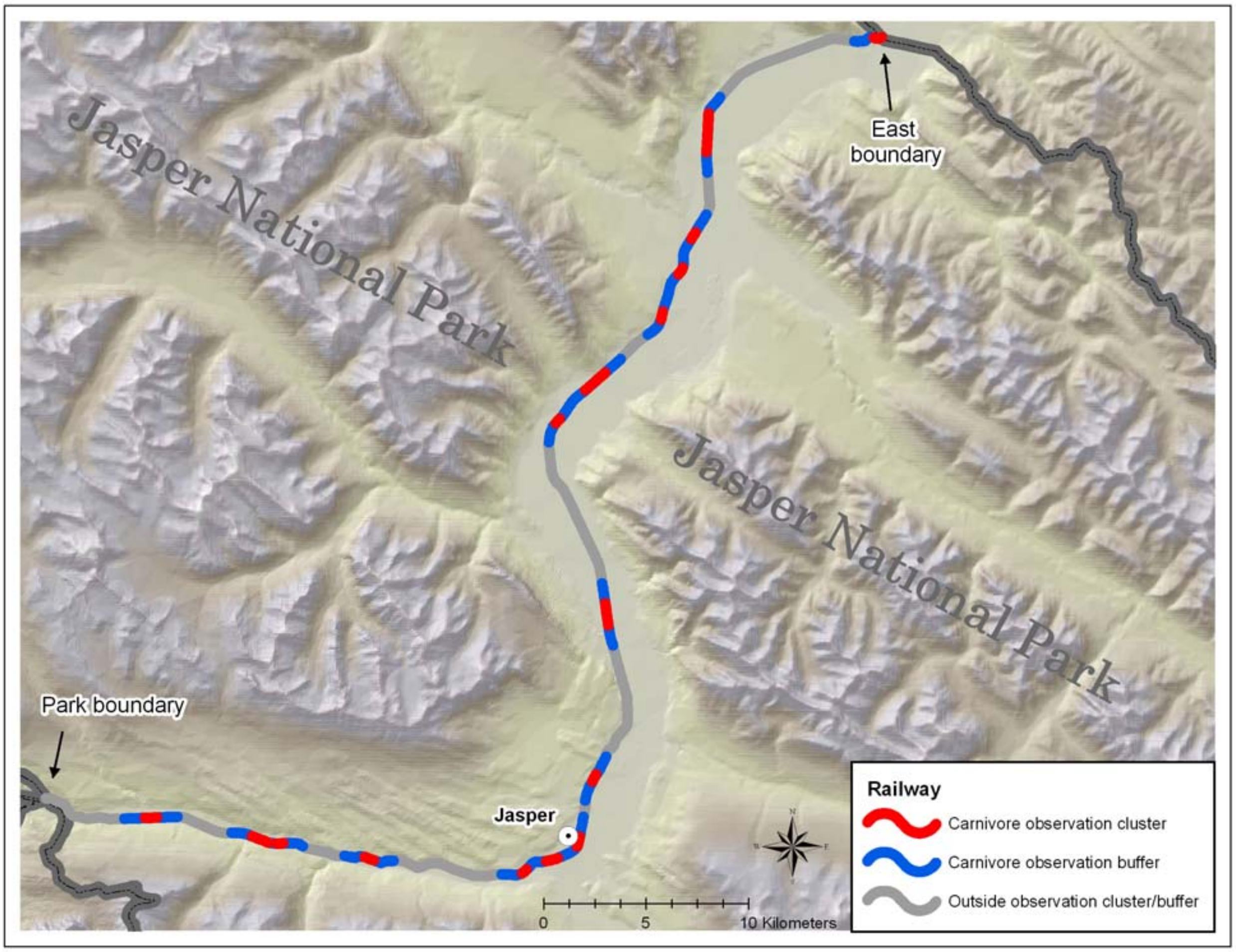

Figure 11. The mortality clusters for the focal species and associated 1 km long buffer zones for the railroad through JNP.

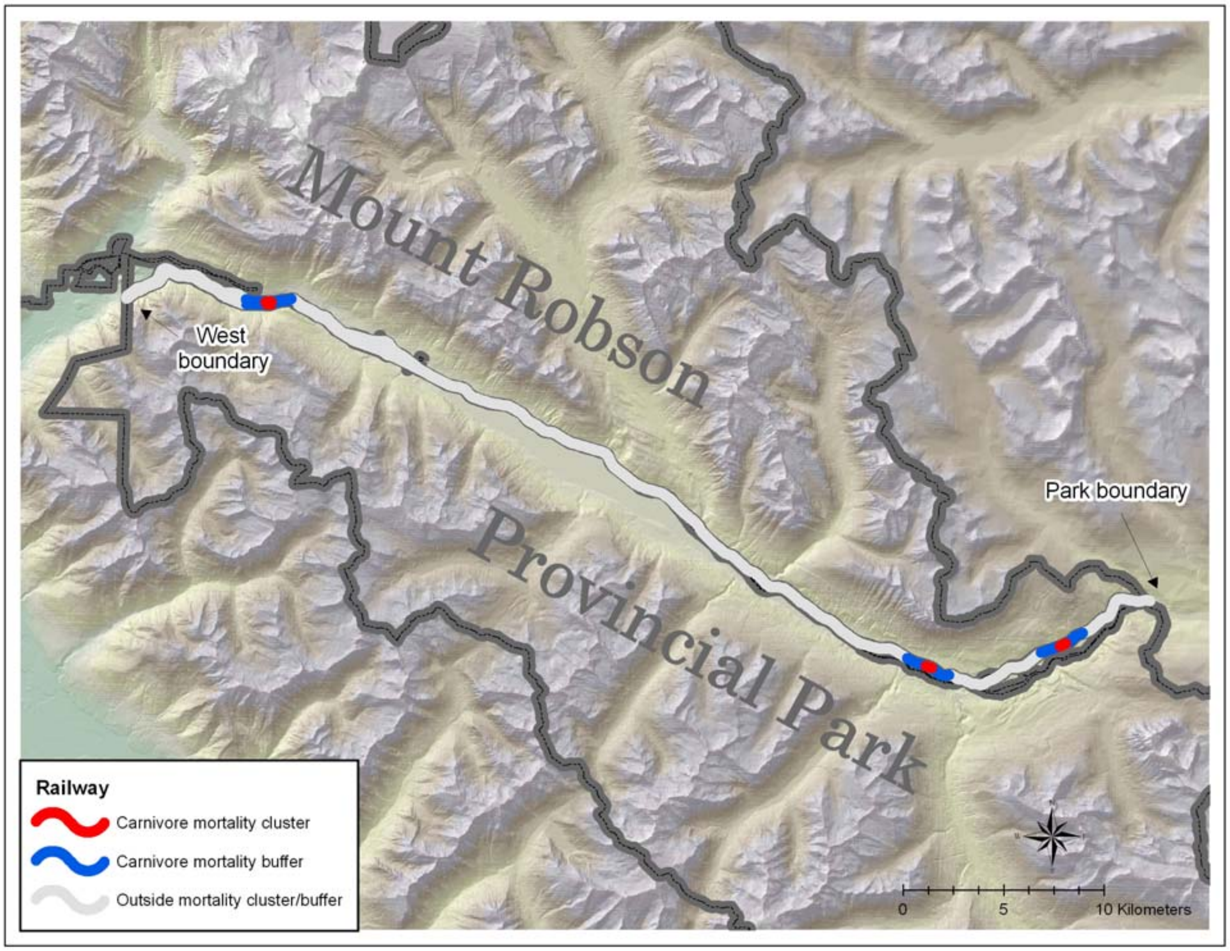

Figure 12. The mortality clusters for the focal species and associated 1 km long buffer zones for the railroad (Albreda and Robson section) through MRPP.

4.5 Prioritization of the Mortality Clusters

The mortality clusters were identified on all available data. For JNP this time period spanned many decades, but for MRPP it only covered a little over one decade. Originally the researchers planned to prioritize the mortality clusters based on the last ten years of data only. However, the researchers continued to use all data for the prioritization of the mortality clusters because of the following reasons:

- The data available for MRPP only covered a little over a decade to begin with, and conducting a second analysis for the prioritization with the last ten years would not have resulted in a meaningful difference with the results of the analysis that included all available data for MRPP.
- The focal species on which the mortality cluster identification was based are all relatively rare species to begin with. Using all available data for the identification of the mortality

clusters resulted in a relatively limited number of observations (see Appendix E). Reducing the time period to the last ten years would have resulted in even further loss of robustness for the prioritization process.

For each mortality cluster the researchers calculated the average mortality value per 100 m (Table 6, Appendix E). The mortality value was based on all available data for the focal species. The higher the average mortality value per 100 m road or railroad segment, the higher the prioritization ranking for a mortality cluster within the four individual road and railroad sections through JNP and MRPP.

Table 6. Prioritization of the mortality clusters for the focal species within each road and railroad section through JNP and MRPP.

Highway/Railroad section	100 m units (km)	Rank value		Highway/Railroad section	100 m units (km)	Rank value
Hwy 16 JNP	43.1-43.4	8.25		Hwy 16 MRPP	38.1-38.4	2.25
Hwy 16 JNP	42.4-42.8	7.00		Hwy 16 MRPP	2.6-2.8	2.00
Hwy 16 JNP	7.8-8.0	5.33		Hwy 16 MRPP	61.3-61.5	2.00
Hwy 16 JNP	36.5-36.9	5.20		Hwy 16 MRPP	20.2-20.7	1.50
Hwy 16 JNP	73.8-74.0	4.33				
Hwy 16 JNP	12.6-12.9	4.00		Railroad JNP	52.9-53.1	6.00
Hwy 16 JNP	30.5-30.9	4.00		Railroad JNP	71.7-72.2	3.50
Hwy 16 JNP	57.7-57.9	4.00		Railroad JNP	0.1-0.4	3.00
Hwy 16 JNP	27.0-27.2	3.67		Railroad JNP	10.9-11.7	2.67
Hwy 16 JNP	45.2-45.6	3.60		Railroad JNP	25.4-25.6	2.00
Hwy 16 JNP	27.6-28.8	3.54		Railroad JNP	27.6-27.8	2.00
Hwy 16 JNP	63.5-64.2	3.50		Railroad JNP	51.2-51.7	2.00
Hwy 16 JNP	49.1-50.0	3.10		Railroad JNP	65.3-65.5	2.00
Hwy 16 JNP	18.8-19.0	3.00		Railroad JNP	49.6-50.0	1.80
Hwy 16 JNP	2.2-2.4	3.00		Railroad JNP	24.4-25.0	1.71
Hwy 16 JNP	39.0-39.5	3.00		Railroad JNP	66.0-66.8	1.67
Hwy 16 JNP	54.5-54.8	3.00		Railroad JNP	15.9-16.2	1.50
Hwy 16 JNP	58.9-59.1	3.00		Railroad JNP	17.8-18.1	1.50
Hwy 16 JNP	48.2-48.9	2.88		Railroad JNP	20.2-20.5	1.50
Hwy 16 JNP	47.5-47.8	2.75		Railroad JNP	46.4-46.7	1.50
Hwy 16 JNP	50.8-51.4	2.71		Railroad JNP	37.4-38.4	1.36
Hwy 16 JNP	25.5-25.7	2.67		Railroad JNP	60.7-61.1	1.20
Hwy 16 JNP	41.5-41.7	2.67		Railroad JNP	9.9-10.6	1.13
Hwy 16 JNP	44.0-44.5	2.67				
Hwy 16 JNP	46.5-46.7	2.67		Railroad MRPP Albr.	5.3-5.5	1.00
Hwy 16 JNP	5.7-5.9	2.67		Railroad MRPP Albr.	12.8-13.0	1.00
Hwy 16 JNP	69.7-69.9	2.67		Railroad MRPP Albr.	51.5-51.7	1.00
Hwy 16 JNP	71.7-71.9	2.67		Railroad MRPP Rob.	8.7-8.9	1.00
Hwy 16 JNP	70.9-71.2	2.50				
Hwy 16 JNP	8.7-9.2	2.50				
Hwy 16 JNP	40.2-40.6	2.40				
Hwy 16 JNP	0.2-0.4	2.33				
Hwy 16 JNP	14.0-14.2	2.33				
Hwy 16 JNP	23.8-24.0	2.33				
Hwy 16 JNP	3.9-4.1	2.33				
Hwy 16 JNP	69.2-69.4	2.33				
Hwy 16 JNP	35.6-35.9	2.25				
Hwy 16 JNP	37.4-37.8	2.20				

4.6 Mortality Clusters Focal Species Excluding Red Fox and Coyote

Data were reanalyzed to exclude two resilient species - coyote and red fox - because the inclusion of these species in the analyses in the previous paragraphs may have led to the identification of road sections where mortality for the focal species is not an immediate conservation concern. Therefore the researchers conducted a separate analysis that excluded red fox and coyote.

The procedure for the analyses was identical to the analyses that included all focal species (see the previous paragraphs in this chapter). However, the six categories of the "focal species mortality values" had different cut-off values (Table 7). Red fox and coyote were not recorded as railroad mortality in MRPP, therefore the exclusion of these species did not affect the identification and prioritization along the railroad in MRPP and no additional analysis was conducted for this railroad section. For this analysis the number of road and railroad mortality observations, excluding red fox and coyote, was summed for each 100 m unit (see Appendix F).

Table 7. Cutoff levels of "focal species mortality values, excluding red fox and coyote" for the road and railroad sections through JNP and MRPP.

Infrastructure Sections	Absent	Very low	Low	Medium	High	Very high
Hwy 16 JNP	0	1	1	1	1	2-4
Hwy 16 MRPP	0	1	1	1	1	2-3
Railroad JNP	0	1	1	1	1	2-6

The mortality clusters for the focal species and the 1 km buffer zones are shown in Figures 13-15. The mortality clusters and buffer zones combined form the mitigation zones. For each mortality cluster the researchers calculated the average mortality value per 100 m (Appendix F). The mortality value was based on all available data for the focal species, excluding the two species. The higher the average mortality value per 100 m road or railroad segment, the higher the prioritization ranking for a mortality cluster.

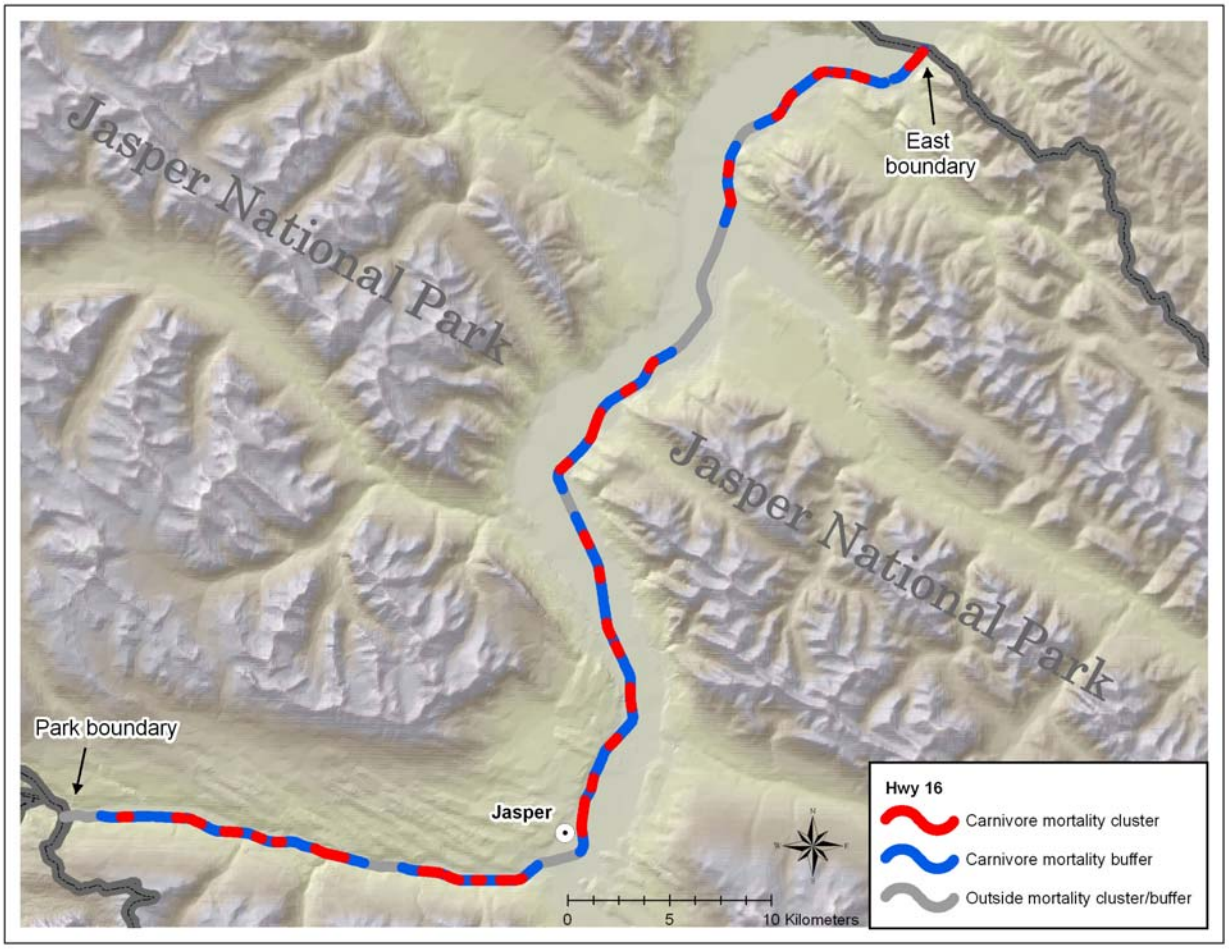

Figure 13. The mortality clusters for the abbreviated focal species (excluding red fox and coyote) and associated 1 km long buffer zones for Hwy 16 through JNP.

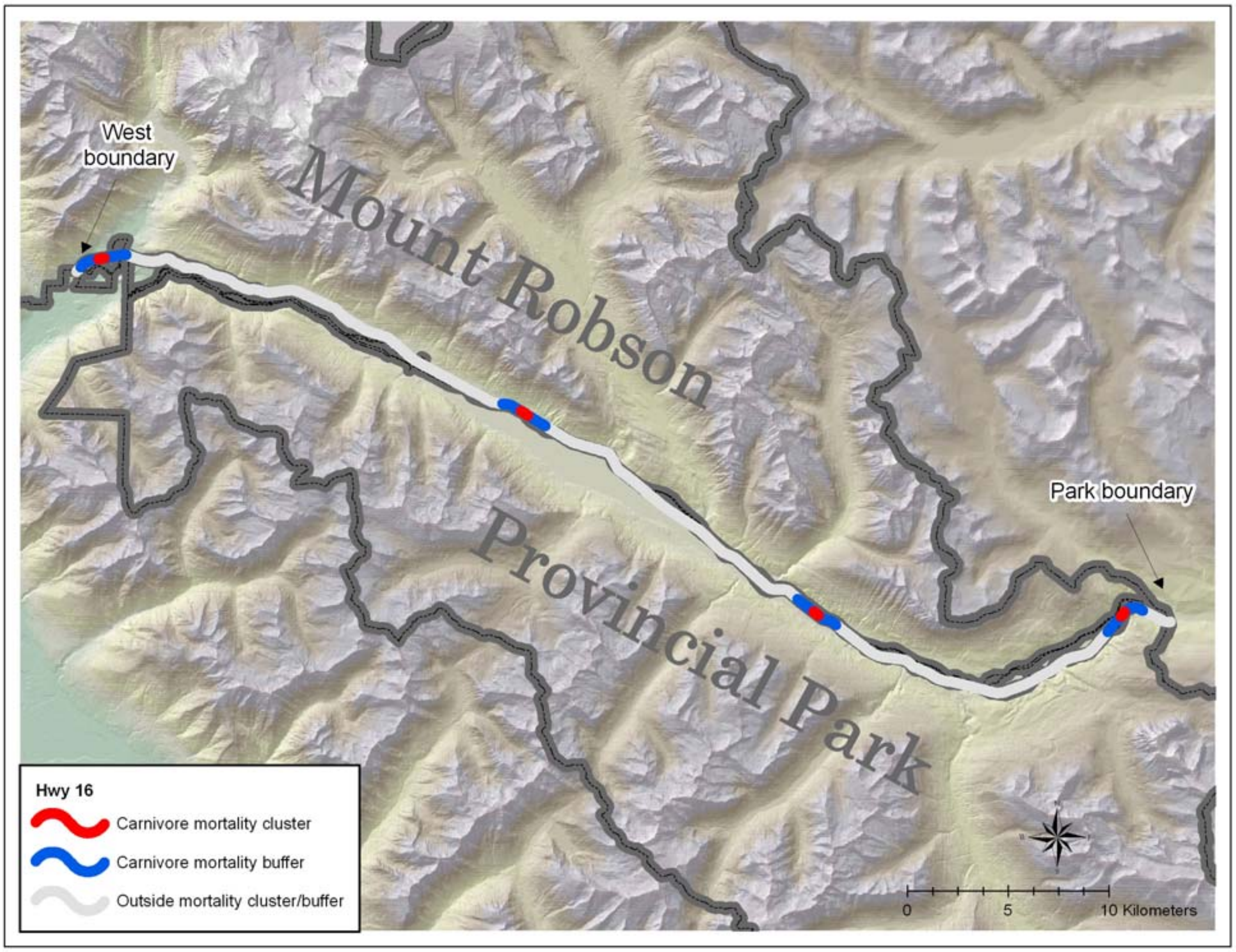

Figure 14. The mortality clusters for the abbreviated focal species (excluding red fox and coyote) and associated 1 km long buffer zones for Hwy 16 through MRPP.

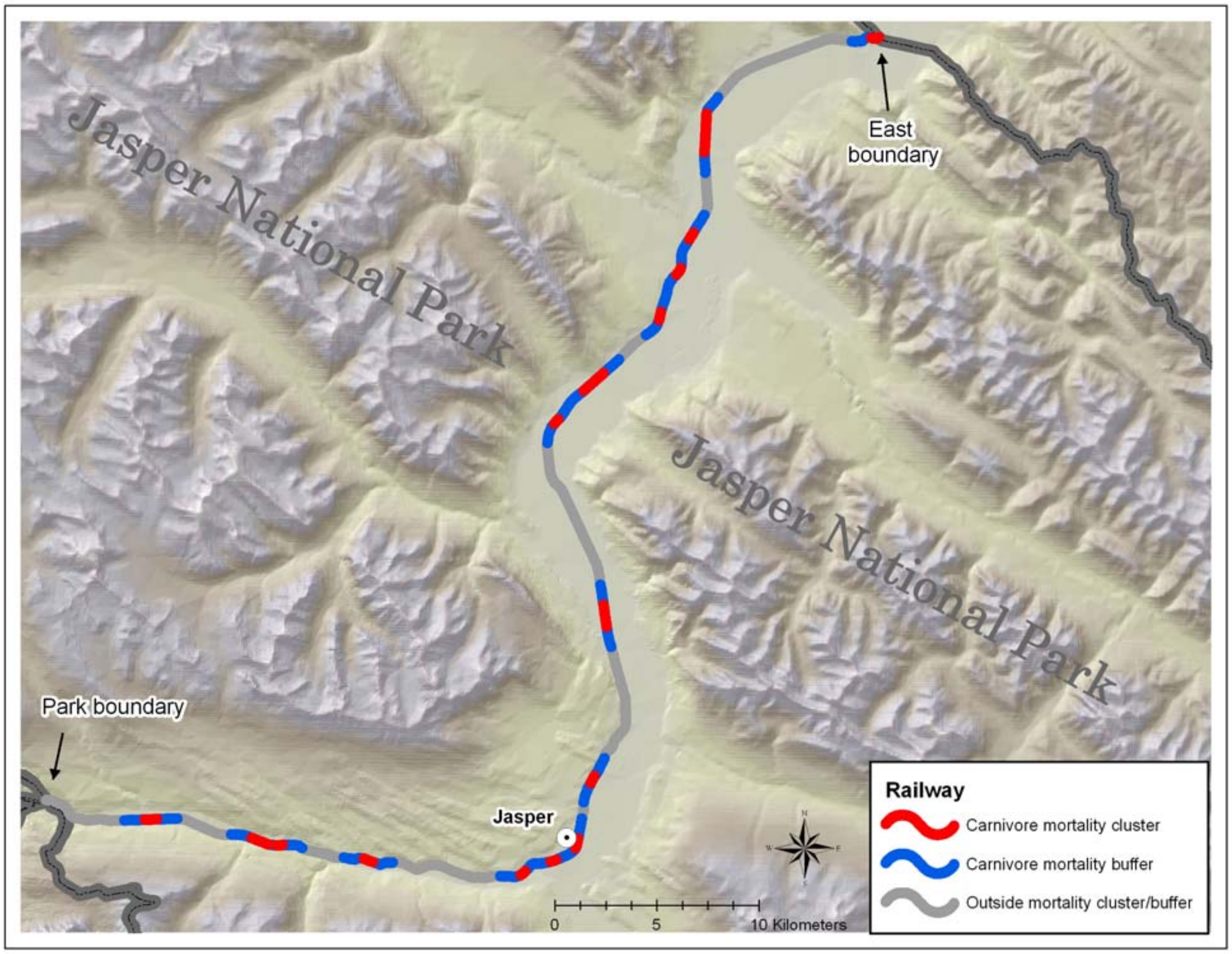

Figure 15. The mortality clusters for the abbreviated focal species (excluding red fox and coyote) and associated 1 km long buffer zones for the railroad through JNP.

The overlap and differences between the mortality clusters based on all focal species and the abbreviated focal species list (i.e., excluding red fox and coyote), is summarized in Table 8. The differences are most pronounced for the infrastructure sections that have the highest search and reporting effort and that tend to include medium sized mammal species most consistently; i.e. Hwy 16 through JNP.

Table 8. The overlap and differences between mortality clusters based on all focal species and the abbreviated focal species list (excluding red fox and coyote) for the road and railroad sections through JNP and MRPP.

Infrastructure Sections	N (%) of 100 m units of mortality clusters for all "focal species" that are not a mortality cluster for the "focal species excluding red fox and coyote"	N (%) of 100 m units of mortality clusters for the "focal species excluding red fox and coyote" that are also included in the mortality clusters for all "focal species"	N (%) of 100 m units of mortality clusters for the "focal species excluding red fox and coyote" that were not included in the mortality clusters for all "focal species"
Hwy 16 JNP	57 units (33.1%)	115 units (63.9%)	65 units (36.1%)
Hwy 16 MRPP	3 units (18.8%)	13 units (100%)	0 units (0%)
Railroad JNP	3 units (3.1%)	95 units (100%)	0 units (0%)

4.7 Prioritization of the Mortality Clusters Excluding Red Fox and Coyote

The prioritization of the mortality clusters, excluding red fox and coyote, was similar to the process described in section 4.5. For each mortality cluster the researchers calculated the average mortality value per 100 m (Table 9, Appendix F). The mortality value was based on all available data for the focal species. The higher the average mortality value per 100 m road or railroad segment, the higher the prioritization ranking for a mortality cluster within the four individual road and railroad sections through JNP and MRPP.

Table 9. Prioritization of the mortality clusters for the focal species (excluding red fox and coyote) within each road and railroad section through JNP and MRPP.

Highway/Railroad section	100 m units (km)	Rank value		Highway/Railroad section	100 m units (km)	Rank value
Hwy 16 JNP	48.7-48.9	3.00		Hwy 16 MRPP	38.1-38.4	2.25
Hwy 16 JNP	57.6-58.1	2.50		Hwy 16 MRPP	2.6-2.8	2.00
Hwy 16 JNP	27.5-27.9	2.40		Hwy 16 MRPP	20.2-20.4	2.00
Hwy 16 JNP	7.7-8.1	2.40		Hwy 16 MRPP	61.3-61.5	2.00
Hwy 16 JNP	63.4-64.3	2.10				
Hwy 16 JNP	0.9-1.1	2.00		Railroad JNP	0.1-0.4	3.00
Hwy 16 JNP	39.0-39.5	2.00		Railroad JNP	9.9-10.6	1.13
Hwy 16 JNP	4.9-5.1	2.00		Railroad JNP	10.9-11.7	2.67
Hwy 16 JNP	43.1-43.3	2.00		Railroad JNP	15.9-16.2	1.50
Hwy 16 JNP	56.5-56.7	2.00		Railroad JNP	17.8-18.1	1.50
Hwy 16 JNP	66.6-66.8	2.00		Railroad JNP	20.2-20.5	1.50
Hwy 16 JNP	67.6-67.8	2.00		Railroad JNP	24.4-25.0	1.71
Hwy 16 JNP	71.7-71.9	2.00		Railroad JNP	25.4-25.6	2.00
Hwy 16 JNP	8.7-8.9	2.00		Railroad JNP	27.6-27.8	2.00
Hwy 16 JNP	28.1-28.8	1.88		Railroad JNP	37.4-38.4	1.36
Hwy 16 JNP	30.5-30.9	1.80		Railroad JNP	46.4-46.7	1.50
Hwy 16 JNP	45.2-45.6	1.80		Railroad JNP	49.6-50.0	1.20
Hwy 16 JNP	49.1-50.2	1.75		Railroad JNP	51.2-51.4	3.00
Hwy 16 JNP	58.6-59.4	1.67		Railroad JNP	52.9-53.1	6.00
Hwy 16 JNP	12.6-12.9	1.50		Railroad JNP	60.7-61.1	1.20
Hwy 16 JNP	23.8-24.1	1.50		Railroad JNP	65.3-65.5	2.00
Hwy 16 JNP	25.5-25.8	1.50		Railroad JNP	66.0-66.8	1.67
Hwy 16 JNP	36.4-36.7	1.50		Railroad JNP	71.7-72.2	3.00
Hwy 16 JNP	40.2-40.5	1.50				
Hwy 16 JNP	42.4-42.7	1.50		Railroad MRPP Albr.	5.3-5.5	1.00
Hwy 16 JNP	5.7-6.0	1.50		Railroad MRPP Albr.	8.7-8.9	1.00
Hwy 16 JNP	54.5-54.8	1.50		Railroad MRPP Albr.	12.8-13.0	1.00
Hwy 16 JNP	55.2-55.5	1.50		Railroad MRPP Rob.	51.5-51.7	1.00
Hwy 16 JNP	64.5-64.8	1.50				
Hwy 16 JNP	70.7-71.2	1.50				
Hwy 16 JNP	74.3-74.6	1.50				
Hwy 16 JNP	68.8-69.4	1.29				
Hwy 16 JNP	0.2-0.6	1.20				
Hwy 16 JNP	14.0-14.4	1.20				
Hwy 16 JNP	3.7-4.1	1.20				
Hwy 16 JNP	34.5-34.9	1.20				
Hwy 16 JNP	47.5-47.9	1.20				

5. SAFE CROSSING OPPORTUNITIES

5.1 Safe Crossing Opportunities

Chapter 4 provided a rationale for the identification and prioritization of road sections that may require mitigation to reduce the number of wildlife-vehicle collisions for the focal species. Wildlife fencing is one of the most effective mitigation measures for reducing wildlife road mortality (Huijser et al., 2008; Clevenger & Huijser, 2011), 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 (e.g. Huijser et al., 2008; Clevenger & Huijser, 2011). Safe crossing opportunities may include e.g. wildlife underpasses and overpasses, or animal detection systems.

5.2 Wildlife Observations On and Near Roads and Railroads in the Mitigation Zones

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

- All reported wildlife mortalities in JNP (OTS database, Parks Canada).
- All reported observations of wildlife (alive) in JNP (OTS database Parks Canada). Note that the search and reporting effort for live observations along Hwy 16 through JNP west of the town of Jasper is believed to be lower than that along Hwy 16 through JNP east of the town of Jasper (Personal communication, Geoff Skinner and Steve Malcolm, 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 Hwy 16 or the railroad in JNP and only selected those observations that were within 200 m of the road or railroad. This procedure related only to JNP and not to MRPP as there were only carcass removal data available for MRPP that were on Hwy 16 or the railroad by definition.

All selected wildlife observations (dead and alive) were "snapped" to the nearest 100 m long road or railroad unit using a GIS (ESRI ArcGIS 9.2). The number of wildlife observations for each focal species (mostly carnivores) and selected other species (large ungulates) (see Table 1) was summed for each 100 m road or railroad unit in JNP (see Appendix F).

5.3 Wildlife Observation Clusters for Hwy 16 and Railroad in JNP

The researchers recognize that not all of the focal species or selected other 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 from a procedure that identified areas where safe crossing opportunities for the focal species and selected other species may have to be provided for. When deciding on the mitigation measures along a particular road sections, the data in Appendix G provide a rationale for the exact location of the safe crossing opportunities if the mitigation measures are to include both the focal species and selected other species.

All selected road and railroad observations (dead and alive) for the focal species and selected other species (see section 5.2) were projected to the nearest 100 m long road or railroad through JNP unit using a GIS (ESRI ArcGIS 9.2). The number of observations was summed for each 100 m unit (see Appendix G). Road and railroad sections with a concentration of observations were identified separately for the road and railroad sections through JNP because the researchers estimated the search and reporting effort to vary greatly between these sections.

The procedure for the road and railroad sections through JNP was as follows:

- All data from all years were selected. For Hwy 16 through JNP this was August 1951 through December 2009. For the railroad through JNP this was October 1952 through December 2009.
- No distinction was made between the different focal species or selected other species; all selected species (see section 2.4) were weighted equally. The number of observations in each 100 m long unit is equivalent to the total number of wildlife observations, regardless of the species, in or adjacent (maximum distance from road or railroad is 200 m) to that 100 m long unit.
- For each 100 m long unit, an “observation value” was calculated by taking the sum of the unit concerned and its two neighboring units (see Appendix G). This procedure was similar to that described in section 4.3.
- Similar to the procedure described in section 4.3 the 100 m units were categorized into one out of six categories based on the “observation value”. The cut-off levels are shown in Table 10.

Table 10. Cutoff levels of "observation values" for the road and railroad sections through JNP.

Road Sections	Absent	Very low	Low	Medium	High	Very high
Hwy 16 JNP	0	1-15	16-30	31-74	76-184	185-5,373
Railroad JNP	0	1-3	4-10	11-30	31-100	101-7,174

Through basing the observation cluster on the longest time period possible; their location is as robust as possible. It incorporates, at least to a certain extent, the dynamics in the ecosystem, including natural succession, fire, and changes in the population size of certain species. The observation clusters for the focal species and selected other species are shown in Figures 16 and 17. The observation clusters are synonymous with road and railroad sections where safe crossing opportunities for the focal species and selected other species may have to be provided for.

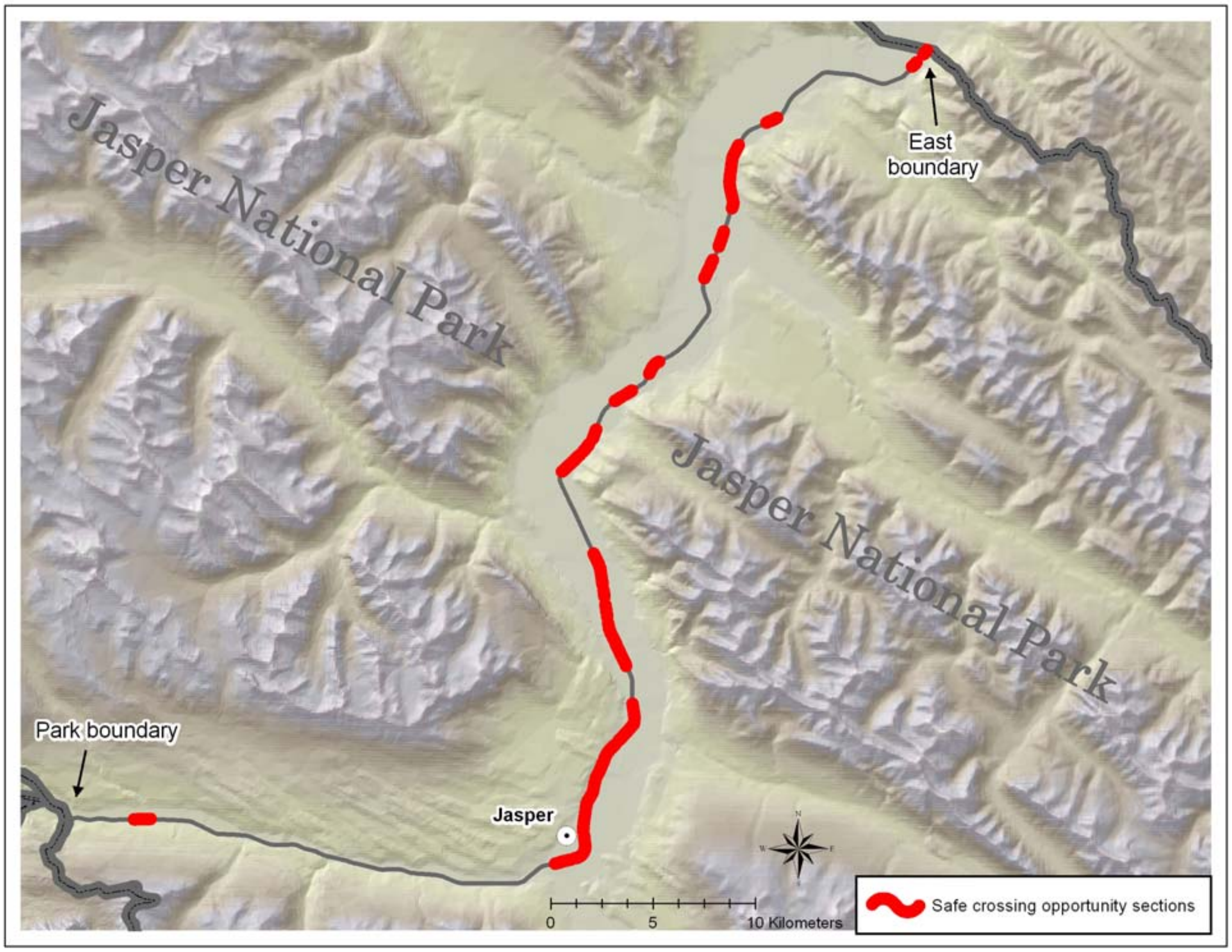

Figure 16. The observation clusters (sections with safe crossing opportunities) for the focal species and selected other species for Hwy 16 through JNP.

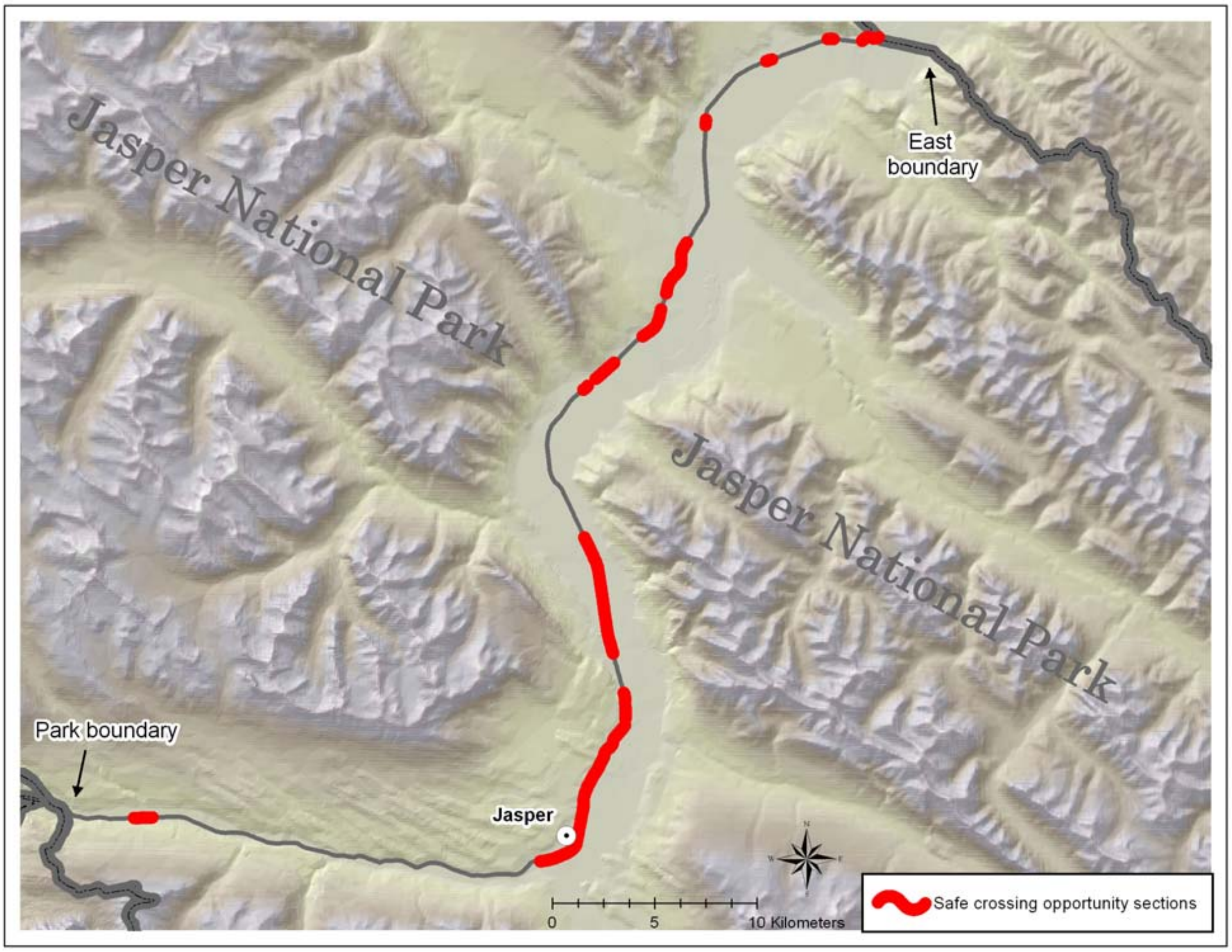

Figure 17. The observation clusters (sections with safe crossing opportunities) for the focal species and selected other species for the railroad through JNP.

5.4 Prioritization of the Wildlife Observation Clusters in the Mitigation Zones

For each observation cluster along Hwy 16 or the railroad through JNP, the researchers summed the 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 11, Appendix G). The higher the average mortality value per 100 m road or railroad segment, the higher the prioritization ranking for a mortality cluster within the two road and railroad sections through JNP. The target species for each observation cluster are summarized in Appendix H.

Table 11. Prioritization of the mortality clusters for the focal species (excluding red fox and coyote) within each road and railroad section through JNP and MRPP.

Highway/Railroad section	100 m units (km)	Rank value		Highway/Railroad section	100 m units (km)	Rank value
Hwy 16 JNP	29.8-30.9	1136.08		Railroad JNP	25.4-25.6	7172.65
Hwy 16 JNP	45.5-50.0	684.30		Railroad JNP	2.4-2.6	906.33
Hwy 16 JNP	25.6-25.9	503.00		Railroad JNP	0.1-0.9	623.67
Hwy 16 JNP	29.1-29.5	464.40		Railroad JNP	43.5-51.9	397.27
Hwy 16 JNP	11.5-14.6	427.28		Railroad JNP	41.9-42.3	388.20
Hwy 16 JNP	50.3-51.6	424.00		Railroad JNP	38.2-39.8	226.76
Hwy 16 JNP	0.9-1.1	416.67		Railroad JNP	42.6-43.1	196.40
Hwy 16 JNP	39.6-41.1	351.69		Railroad JNP	17.6-18.3	179.25
Hwy 16 JNP	38.9-39.4	341.33		Railroad JNP	10.2-10.4	172.00
Hwy 16 JNP	23.6-24.3	298.25		Railroad JNP	23.7-24.8	150.42
Hwy 16 JNP	35.4-36.9	261.44		Railroad JNP	5.6-5.8	143.67
Hwy 16 JNP	0.1-0.3	251.33		Railroad JNP	71.9-72.7	142.75
Hwy 16 JNP	15.9-16.6	243.63		Railroad JNP	34.0-38.0	115.46
Hwy 16 JNP	51.9-52.6	200.00		Railroad JNP	18.5-19.2	97.63
Hwy 16 JNP	26.2-26.5	188.00		Railroad JNP	20.1-21.7	83.29
Hwy 16 JNP	9.1-9.6	185.83		Railroad JNP	16.5-17.4	70.30
Hwy 16 JNP	37.3-37.5	182.33				
Hwy 16 JNP	43.1-43.7	173.71				
Hwy 16 JNP	28.3-28.7	160.00				
Hwy 16 JNP	17.4-18.3	152.70				
Hwy 16 JNP	44.0-45.1	142.92				
Hwy 16 JNP	38.0-38.5	139.33				
Hwy 16 JNP	73.3-74.0	135.13				

6. LOCAL KNOWLEDGE AND EXPERIENCE

In addition to the observation clusters (see Chapter 5, Appendix G) in JNP, the researchers conducted interviews with agency personnel with local knowledge and experience of wildlife road and railroad mortality and live wildlife sightings in JNP and MRPP (Figures 18-21, Tables 12 and 13). These data showed the researchers whether additional species occurred or were perceived to occur in addition to the data presented in Appendix F and G. This information may be useful when deciding where to locate safe crossing opportunities should be provided for and what species they should be designed for.

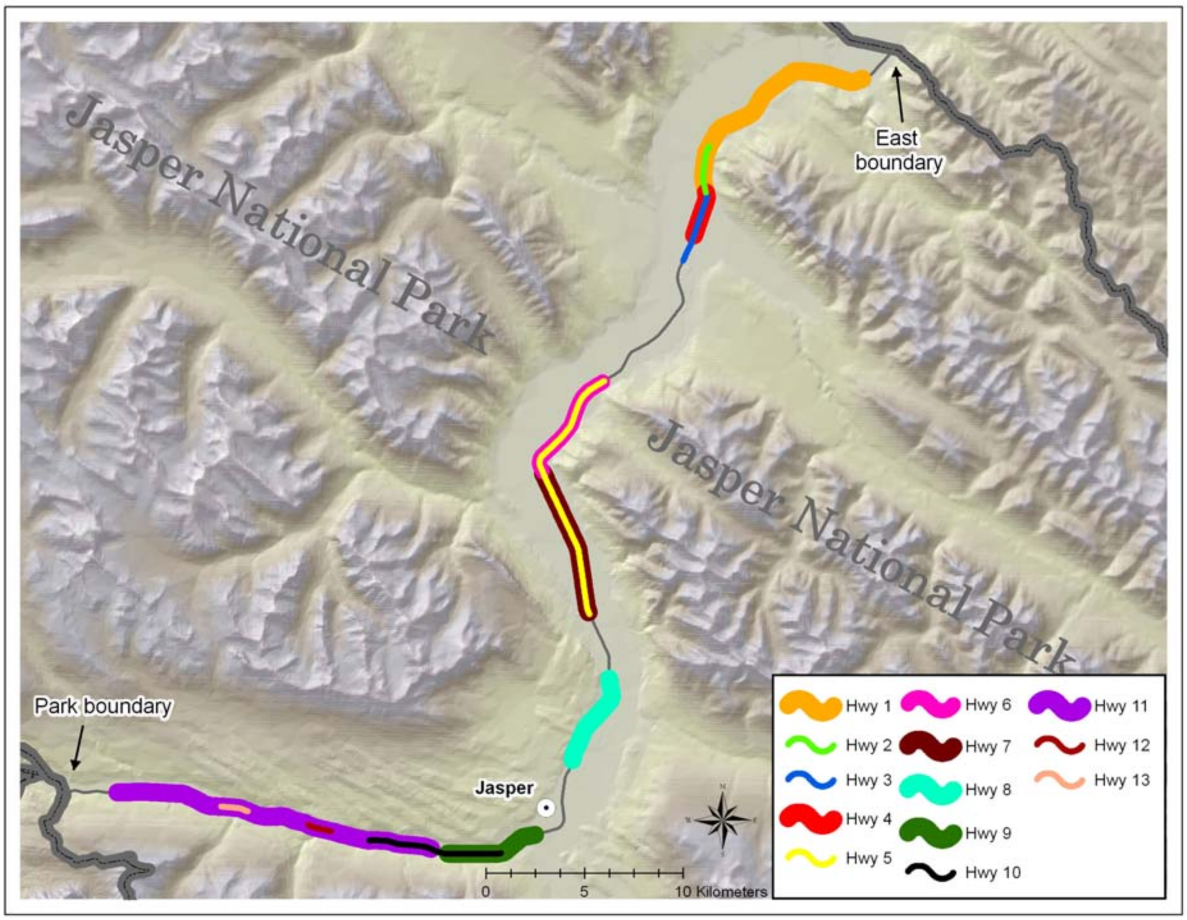

Figure 18. Local knowledge and experience with wildlife observations along Hwy 16 in JNP (see Table 12 for the legend).

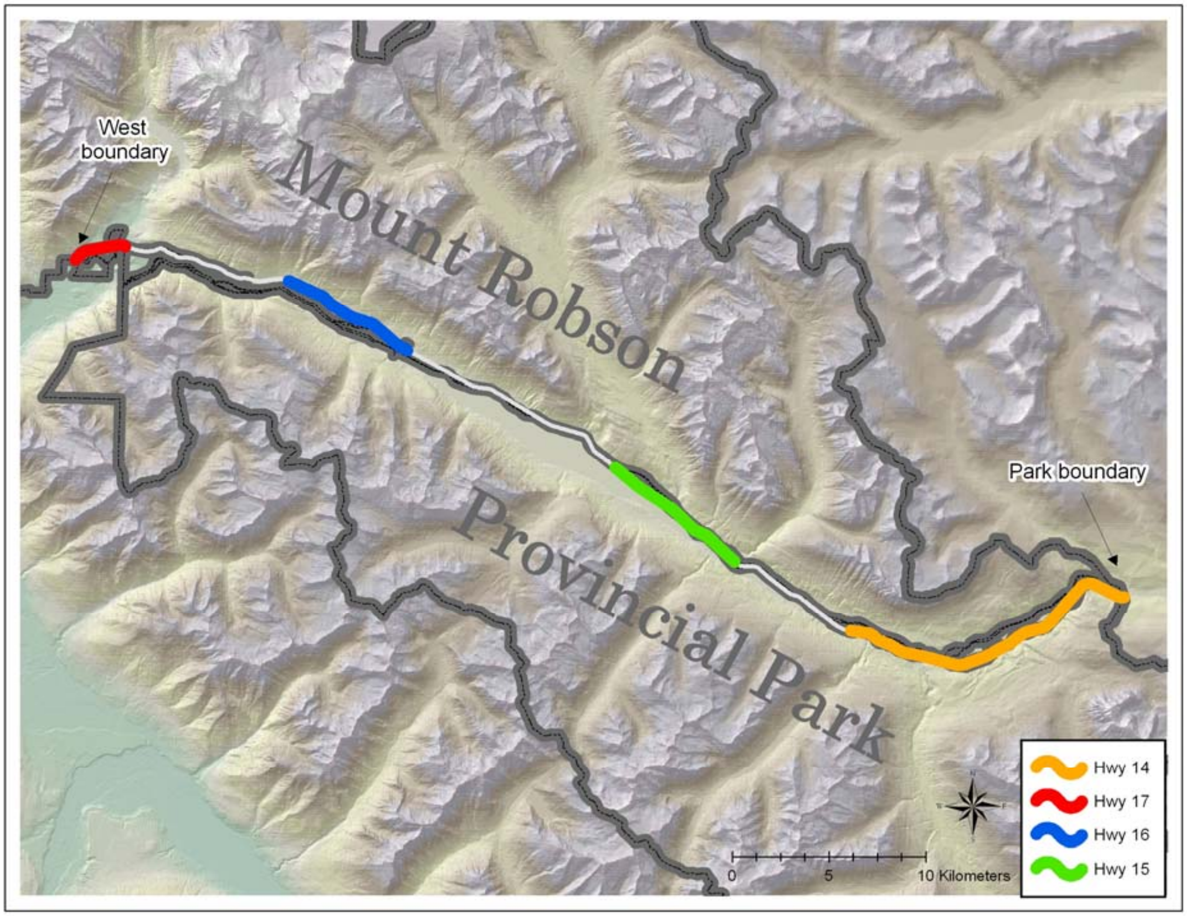

Figure 19. Local knowledge and experience with wildlife observations along Hwy 16 in MRPP (see Table 12 for the legend).

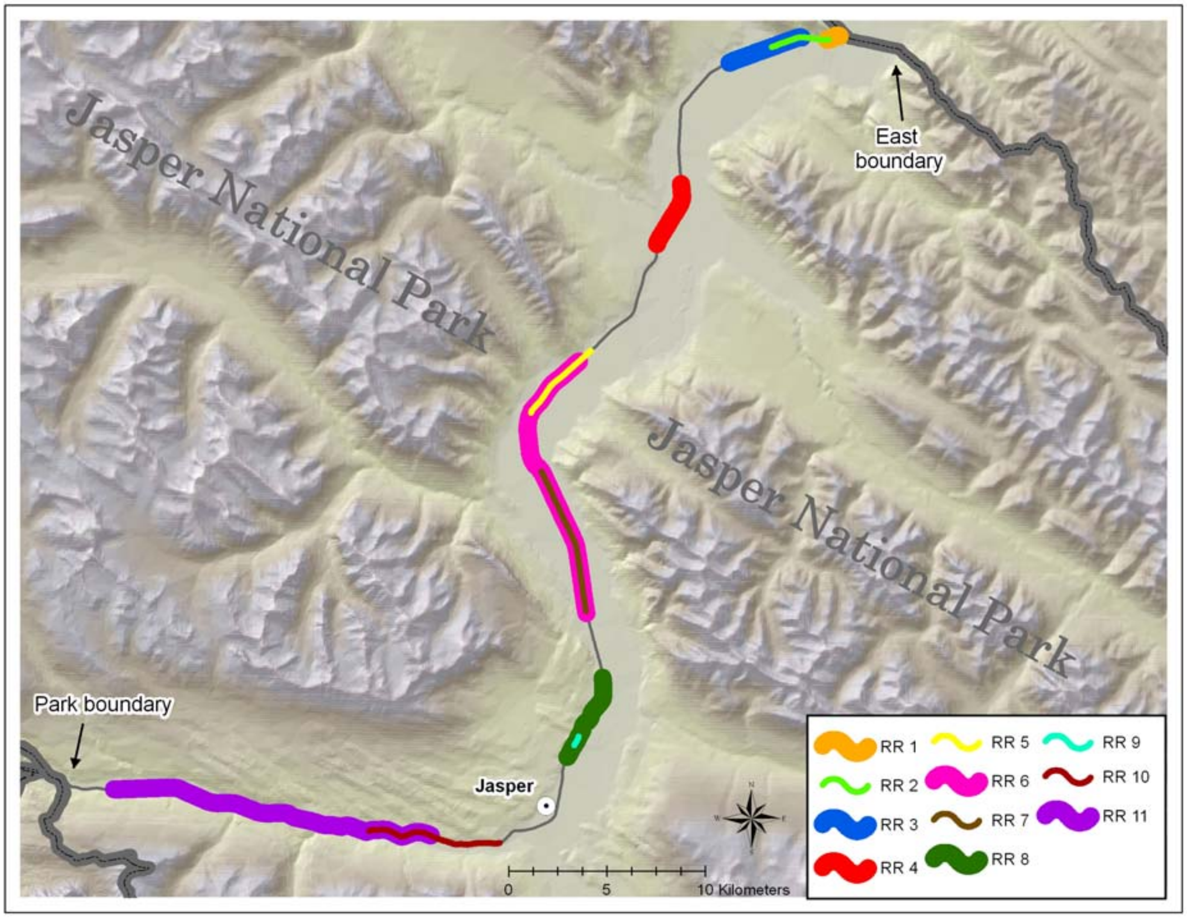

Figure 20. Local knowledge and experience with wildlife observations along the railroad in JNP (see Table 13 for the legend).

Figure 21. Local knowledge and experience with wildlife observations along the railroad in MRPP (see Table 13 for the legend).

Table 12. Key to Figures 15-18. Local =knowledge and experience with regard to wildlife observations (dead and alive) along Hwy 16 through JNP and MRPP.

Number on Map	Hwy 16 100 m units	Comments	Source
Hwy 1	23-141	White-tailed deer and mule deer, alive and dead	Geoff Skinner
Hwy 2	118-141	Disaster point, bighorn sheep on road (dead and alive), mountain goats (rare) alive	Geoff Skinner
Hwy 3	141-178	In box: white-tailed deer, mule deer, wolf, alive and dead, pinch point for animal movements, licks	Steve Malcolm
Hwy 4	142-164	Wolf, alive and dead	Geoff Skinner
Hwy 5	259-394	Elk feeding, especially in winter, alive and dead	Steve Malcolm
Hwy 6	260-317	12 mi point, Bighorn sheep Alive and dead	Geoff Skinner
Hwy 7	319-393	Elk and wolves, alive and dead	Geoff Skinner
Hwy 8	430-477	Bighorn sheep alive and dead	Geoff Skinner
Hwy 9	527-573	Many species, Alive and dead Historical corridor to important caribou habitat (currently unoccupied) north of road and railroad	Geoff Skinner
Hwy 10	547-614	Some black bear mortality on road	Steve Malcolm
Hwy 11	583-746	Elk, moose, some wolves, alive and dead	Geoff Skinner
Hwy 12 Hwy 13	635-646 679-692	Creek crossings, wolverines, wolves, alive	Geoff Skinner
Hwy 14	1-110	Reflector section – border, all species, incl. wolves, dead	Wayne van Velzen and Lucille Green
Hwy 15	234-312	Marsh complex," moose marsh", moose, dead	Wayne van Velzen and Lucille Green
Hwy 16	440-511	Cottonwood creek – red pass black bears, moose, elk, dead and alive Mowed vegetation and blue berries are an attractant, elevation changes less abruptly, good habitat, south facing slopes	Wayne van Velzen and Lucille Green
Hwy 17	600-628	Around visitor center, elk (little mortality), and black bear and deer (dead and alive)	Wayne van Velzen and Lucille Green

Table 13. Key to Figures 15-18. Local =knowledge and experience with regard to wildlife observations (dead and alive) along the railroad through JNP and MRPP.

Number on Map	Railroad 100 m units	Comments	Source
RR 1	5-11	Brule tunnel, bighorn sheep at entrance tunnel (probably west end), mortality	Geoff Skinner
RR 2	11-140	White-tailed deer and mule deer, alive and dead	Geoff Skinner
RR 3	25-63	Moose dead	Steve Malcolm
RR 4	137-170	Bighorn sheep (ram pasture) dead and alive Also wolf and black bear and grizzly bear on railroad bridge	Steve Malcolm
RR 5	238-281	White-tailed deer, mule deer, elk, alive and dead	Geoff Skinner
RR 6	246-389	Elk feeding, especially in winter, alive and dead	Steve Malcolm
RR 7	314-388	Elk and wolves, alive and dead	Geoff Skinner
RR 8	424- 469	Bighorn sheep alive and dead	Geoff Skinner
RR 9	458-562	Grain spills, bleak bear attraction, elk predator refuge, alive and dead	Geoff Skinner
RR 10	533-601	Spilled grain, back bear mortality	Steve Malcolm
RR 11	569-735	Elk, moose, some wolves, alive and dead	Geoff Skinner
RR 12	1-102	Reflector section – border, all species, incl. wolves, dead	Wayne van Velzen and Lucille Green
RR 13	225-304	Marsh complex," moose marsh", moose, dead	Wayne van Velzen and Lucille Green

7. MITIGATION MEASURES

7.1 Recommended Mitigation Measures

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. 2008, Clevenger & Huijser 2011). Only wildlife fencing and animal detection systems have shown to be able to reduce WVCs with large mammals substantially (>80%). It is important to note however, that animal detection systems should still be considered experimental whereas the estimate for the effectiveness of wildlife fencing in combination with wildlife underpasses and overpasses is much more robust. 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 14.

Mitigation measures that involve 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 costly 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. 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 16 through JNP and MRPP. For a summary of the pros and cons of a reduction of the maximum speed limit, see Table 14.

Table 14. 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 over long distances (at least several kilometers).	Barrier for wildlife; combine with safe crossing opportunities. Affects landscape aesthetics and sense of connectedness of the drivers to the surrounding areas. 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.	Lowering speed limit may lead to increased speed dispersion and higher crash rates. Design speed will make drivers, especially infrequent visitors, want to drive the perceived safe speed. 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	87% reduction in WVCs for large mammals expected, but this estimate in WVC reduction	Not suitable for very high traffic volumes.

systems	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.	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 road managing agencies 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.

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 22 and 23), in combination with wildlife underpasses and overpasses, to be the primary recommended mitigation measures for the reduction of WVCs along Hwy 16 and the railroad through JNP and MRPP. 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 24) mitigation measures to have potential for reducing WVCs along Hwy 16 and the railroad through JNP and MRPP. However, these mitigation measures are classified as either “not necessarily effective but raising awareness and public support for mitigation measures that are effective”, “supportive” (secondary measures) or “experimental”.

Figure 22. A 2.4 m high fence with buried apron along the Trans-Canada Highway in Banff National Park (Phase 3-A) (© Tony Clevenger).

Figure 23. A 2.4 m high wildlife fence along the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (© Marcel Huijser).

Figure 24. 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 25). 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 26). Wildlife guards have also been used on major roads at fence ends (Figure 27).

Figure 25. 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).

Figure 26. The Boulder Field at the Fence End at Dead Man's Flats Along the Trans-Canada Highway East of Canmore, Alberta, Canada (© Bruce Leeson).

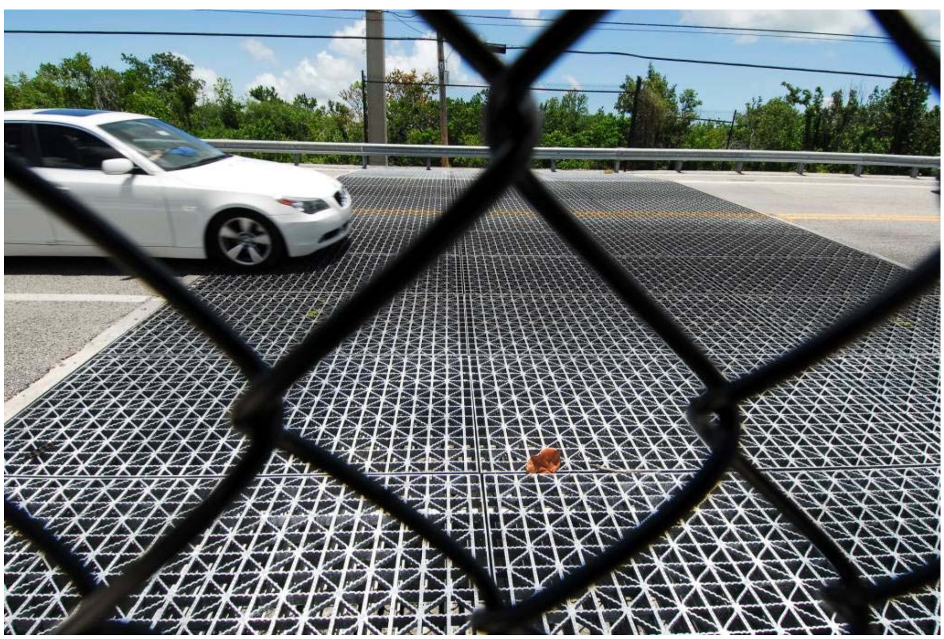

Figure 27. Wildlife guard at a fence end on the 2-lane US Hwy 1 on Big Pine Key, Florida, USA (© Marcel Huijser).

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 28 through 30). 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 in height.

Figure 28. A jump-out along a 2.4 m (8 ft) high fence along US 93 in Montana, USA (© Marcel Huijser).

Figure 29. A jump-out along a 2.4 m (8 ft) high fence along US 93 in Montana, USA (© Marcel Huijser).

Figure 30. 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).

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 31-32) or gates (Figure 33 and 34) can be installed at access roads. In addition, access points for people, e.g. hikers, can be provided for (Figure 35 and 36).

Figure 31. A wildlife guard at an access road of the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (© Marcel Huijser)

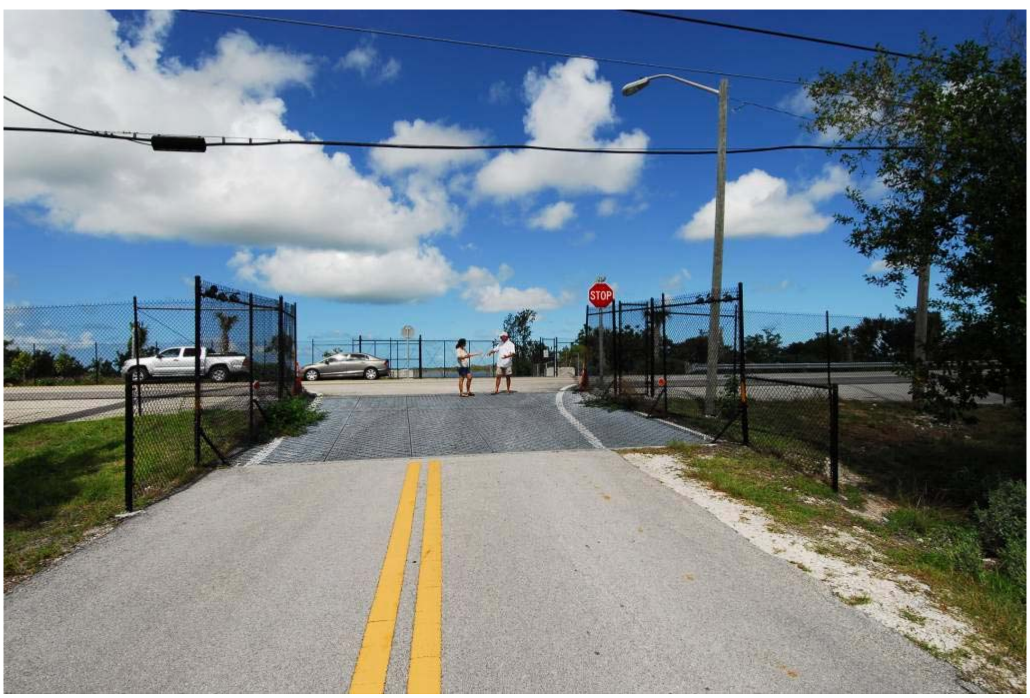

Figure 32. A wildlife guard at an access road of the 2-lane US Highway 1 on Big Pine Key, Florida, USA (© Marcel Huijser)

Figure 33. A gate at an access road of the 2-lane US Highway 93 on the Flathead Reservation in Montana, USA (© Marcel Huijser)

Figure 34. A gate at an access road of the 2-lane US Highway 1 on Big Pine Key, Florida, USA (© Marcel Huijser)

Figure 35: 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 36: 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. bighorn sheep, white-tailed deer, mule deer and elk).
- 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.

Full scale population viability analyses can be very helpful to compare the effectiveness of different configurations of safe crossing opportunities. Such analyses require substantial and detailed data and they may be relatively expensive (see Chapter 8).

For this report the recommended distance between safe crossing opportunities was set to be equal to the diameter of the home range of the species concerned (Figure 37, Appendix I). 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 38). 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.

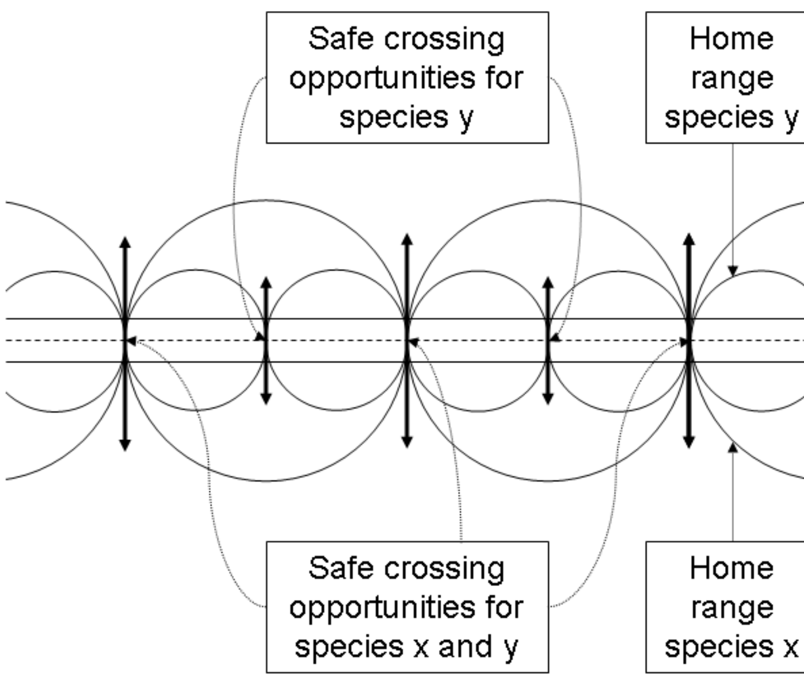

Figure 37. Schematic representation of home ranges for two theoretical species projected on a road and the distance between safe crossing opportunities (distance is equal to the diameter of their home range (Appendix I)).

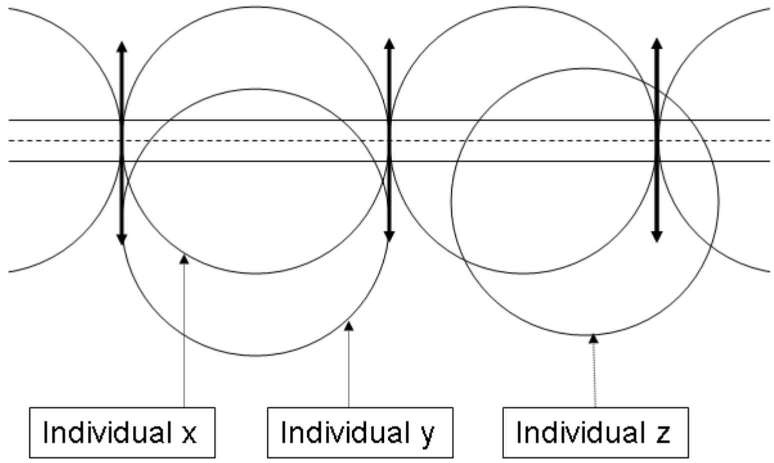

Figure 38. Schematic representation of home range for an individual (x) that has the center of its home range on the center of the road (access to two safe crossing opportunities), an individual (y) that has the center of its home range slightly off the center of the road exactly in between two safe 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 15) (Figure 39 through 47). 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 or semi-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 & Huijser, 2011). 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 15 classifies crossing structures based on their dimensions, there is no generally agreed upon definition of different types of crossing structures. 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 16 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.

Should at grade crossing opportunities be implemented in combination with wildlife fencing, extreme care must be taken to discourage wildlife from wandering off in between the fences in the fenced road corridor. 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.

Table 15. Dimensions of the safe crossing opportunities 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 39. Red Earth overpass on the Trans-Canada Highway (© Tony Clevenger).

Figure 40. Wildlife overpass ("Schwarzgraben") across a 2-lane road (B31) in southern Germany (© Edgar van der Grift).

Figure 41. 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 42. 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 43. 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 44. 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 45. A small-medium mammal pipe (“badger pipe”) in The Netherlands (© Marcel Huijser).

Figure 46. 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 47. 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).

Table 16. Suitability of different types of mitigation measures for various species. ● Recommended/Optimum solution; ʘ Possible if adapted to local conditions; ⊗ Not recommended; ? Unknown, more data are required; — Not applicable (Clevenger & Huijser, 2011; 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	●	●	ʘ	⊗	⊗	●
Moose	●	●	ʘ	⊗	⊗	●
Caribou	?	?	?	?	⊗	?
Mountain goat	●	●	ʘ	⊗	⊗	●
Bighorn sheep	●	●	ʘ	⊗	⊗	●
Carnivores						
Fisher	?	?	?	?	?	⊗
Wolverine	●	?	?	?	⊗	⊗
Bobcat	●	●	●	●	●	⊗
Canada lynx	●	?	?	?	⊗	⊗
Cougar	●	●	●	⊗	⊗	⊗
Red fox	●	●	●	●	●	⊗
Coyote	●	●	●	●	●	⊗
Wolf	●	●	ʘ	⊗	⊗	⊗
Black bear	●	●	●	⊗	⊗	●
Grizzly bear	●	ʘ	ʘ	⊗	⊗	●

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 (this Chapter and Appendix E, F, G, and H).

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 200 m from the road) within the mortality clusters of the focal species. 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 somewhat 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 recommend having at least one crossing opportunity for each focal species mortality cluster and each wildlife observation cluster (Appendix G) in a mitigation zone. However, if crossing structures are substantially closer than the diameter of the home range of the focal species or selected other species (Appendix I), fewer structures are proposed. On the other hand, some wildlife observation clusters are over a road length that is greater than the home range of the target species, and here multiple crossing structures should be provided within a wildlife observation cluster. A mitigation zone consists of one or more wildlife mortality clusters and their adjacent buffer zones. If a mitigation zone is longer than the diameter of the home range of the target species, multiple safe crossing opportunities are recommended.

The procedure to identify the target species and the type and dimensions of safe crossing opportunities was as follows:

For Hwy 16 and railroad through JNP

- The mortality clusters for the abbreviated focal species list (i.e., excluding red fox and coyote), and their buffer zones (Appendix F) were used to identify mitigation zones. A mitigation zone can include one mortality cluster with its buffer zones, or, if the buffer zones from neighboring mortality clusters overlap, a mitigation zone can include multiple mortality clusters and their buffer zones.
- The start and end of the mitigation zones were identified through their 100 m road unit numbers.
- The observation data (alive and dead) of all focal species and selected other species (Appendix G) were summarized for each mitigation zone to investigate which species were most often observed in the mitigation zones and for which species the safe crossing opportunities need to be designed for.
- The researchers identified the focal species (excluding red fox and coyote) that had been observed at least once in a mitigation zone (Appendix H). In addition, the researchers identified all species (focal species and selected other species) that represented at least 10% of all observations in the mitigation zone (Appendix H).
- Large overspan bridges and large mammal underpasses are estimated to be appropriate for most large mammal species (see paragraph 7.3), including the focal species and selected other species. Therefore these types of safe crossing opportunities were recommended for most mitigation zones. However, if there were at least 25 grizzly bear observations in a mitigation zone, the researchers also suggested wildlife overpasses.

For Hwy 16 and railroad through MRPP

- The mortality clusters for the abbreviated focal species list (i.e., excluding red fox and coyote), and their buffer zones (Appendix F) were used to identify mitigation zones. A mitigation zone can include one mortality cluster with its buffer zones, or, if the buffer zones from neighboring mortality clusters overlap, a mitigation zone can include multiple mortality clusters and their buffer zones.
- The start and end of the mitigation zones were identified through their 100 m road unit numbers.
- There were no live observations for species along the road and railroad through MRPP. Therefore the researchers summarized the mortality data of all focal species and selected other species (Appendix F) for each mitigation zone to investigate which species were most often observed as road or railroad mortality in the mitigation zones and for which species the safe crossing opportunities may need to be designed for.
- The researchers identified the focal species (excluding red fox and coyote) that had been observed at least once in a mitigation zone (Appendix H). In addition, the researchers identified all species (focal species and selected other species) that represented at least 10% of all observations in the mitigation zone (Appendix H).
- Large overspan bridges and large mammal underpasses are estimated to be appropriate for most large mammal species (see paragraph 7.3), including the focal species and selected other species considered in this report. Therefore these types of safe crossing opportunities were recommended for most mitigation zones. However, if there were at least 25 grizzly bear observations in a mitigation zone, the researchers also suggested wildlife overpasses.

The target species and the type and number of suggested safe crossing opportunities for each mitigation zone are listed in Appendix H. The location of the mitigation zones and the suggested mitigation measures is shown in figures 48-51.

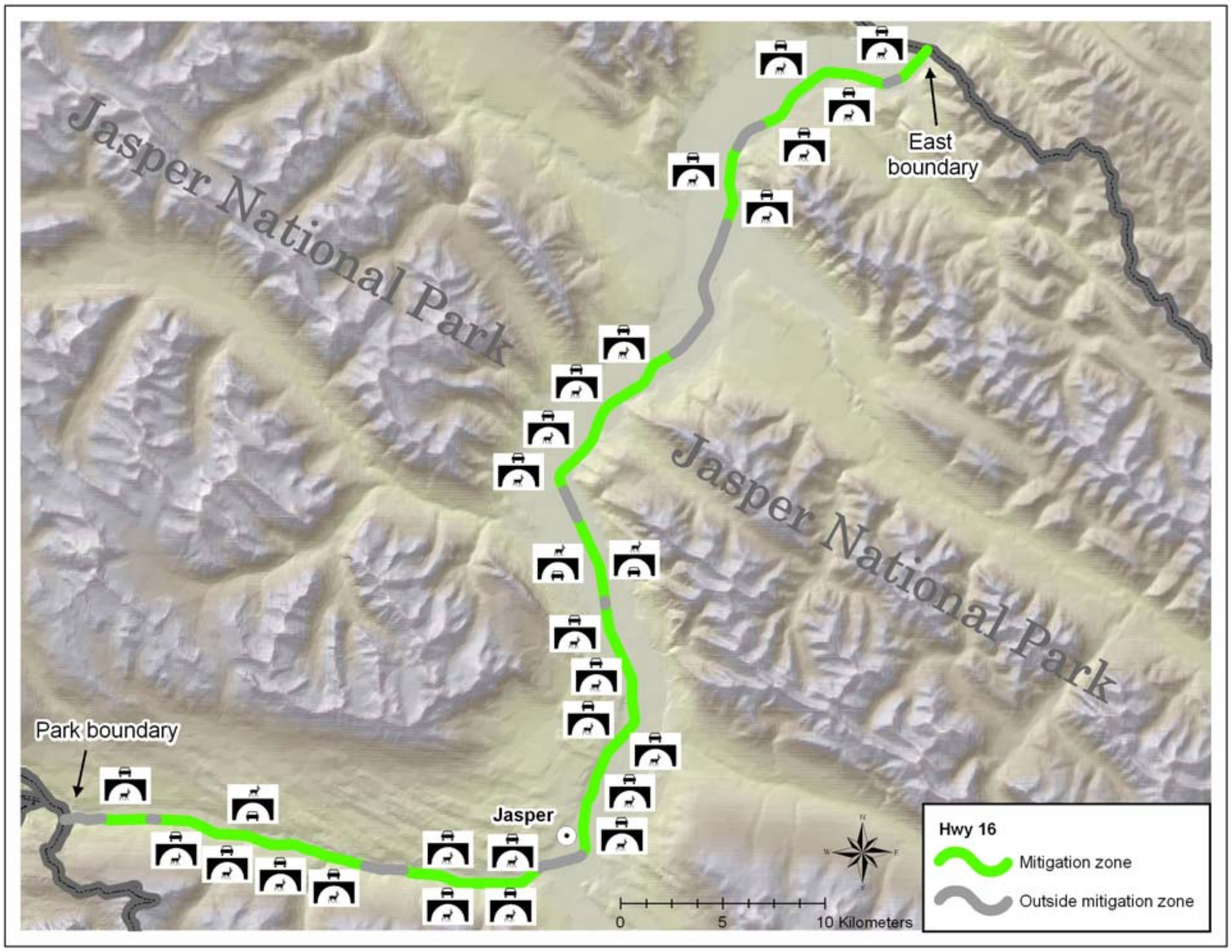

Figure 48. The mitigation zones and the suggested type and number of safe crossing opportunities per mitigation zone for Hwy 16 through JNP.

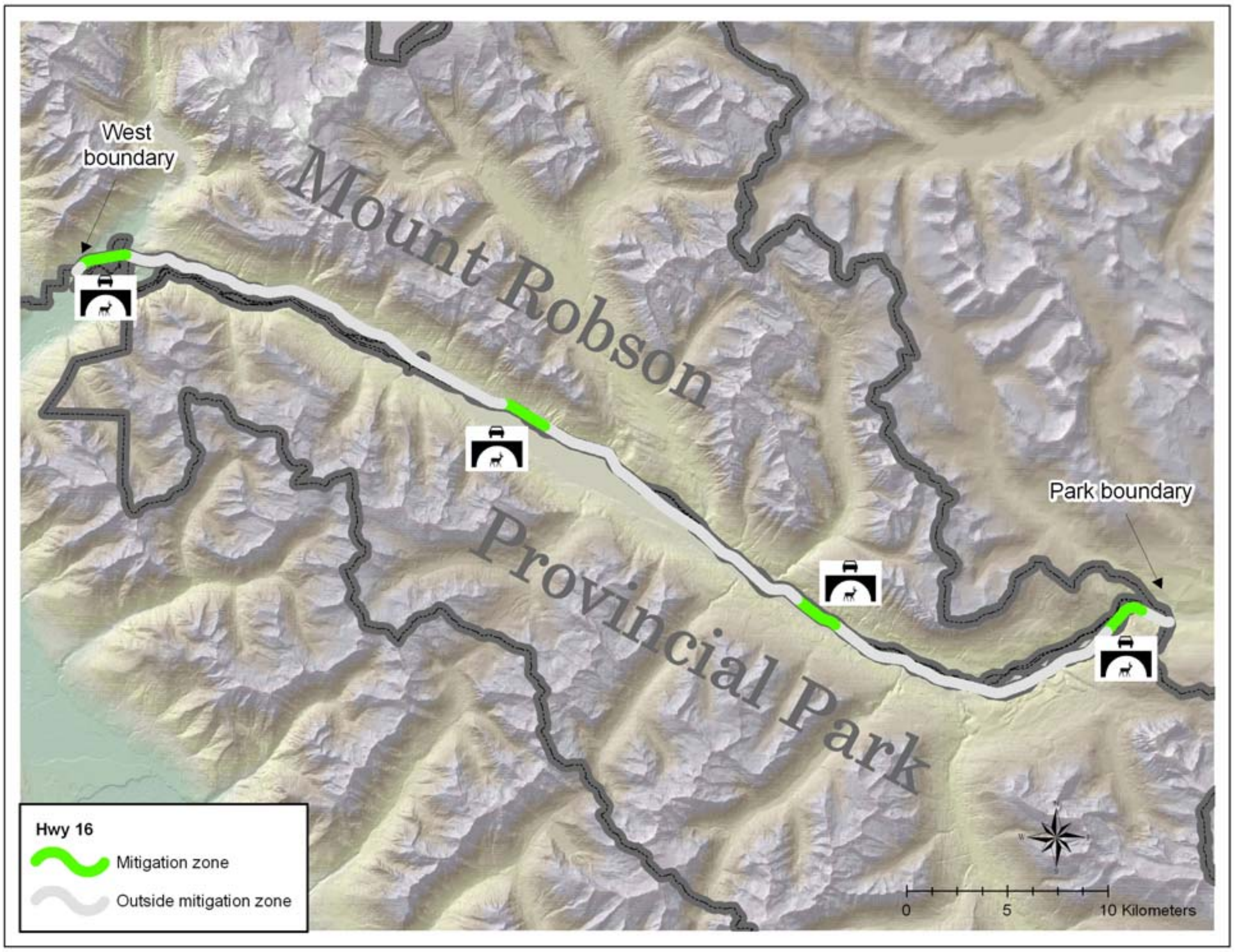

Figure 49. The mitigation zones and the suggested type and number of safe crossing opportunities per mitigation zone for Hwy 16 through MRPP.

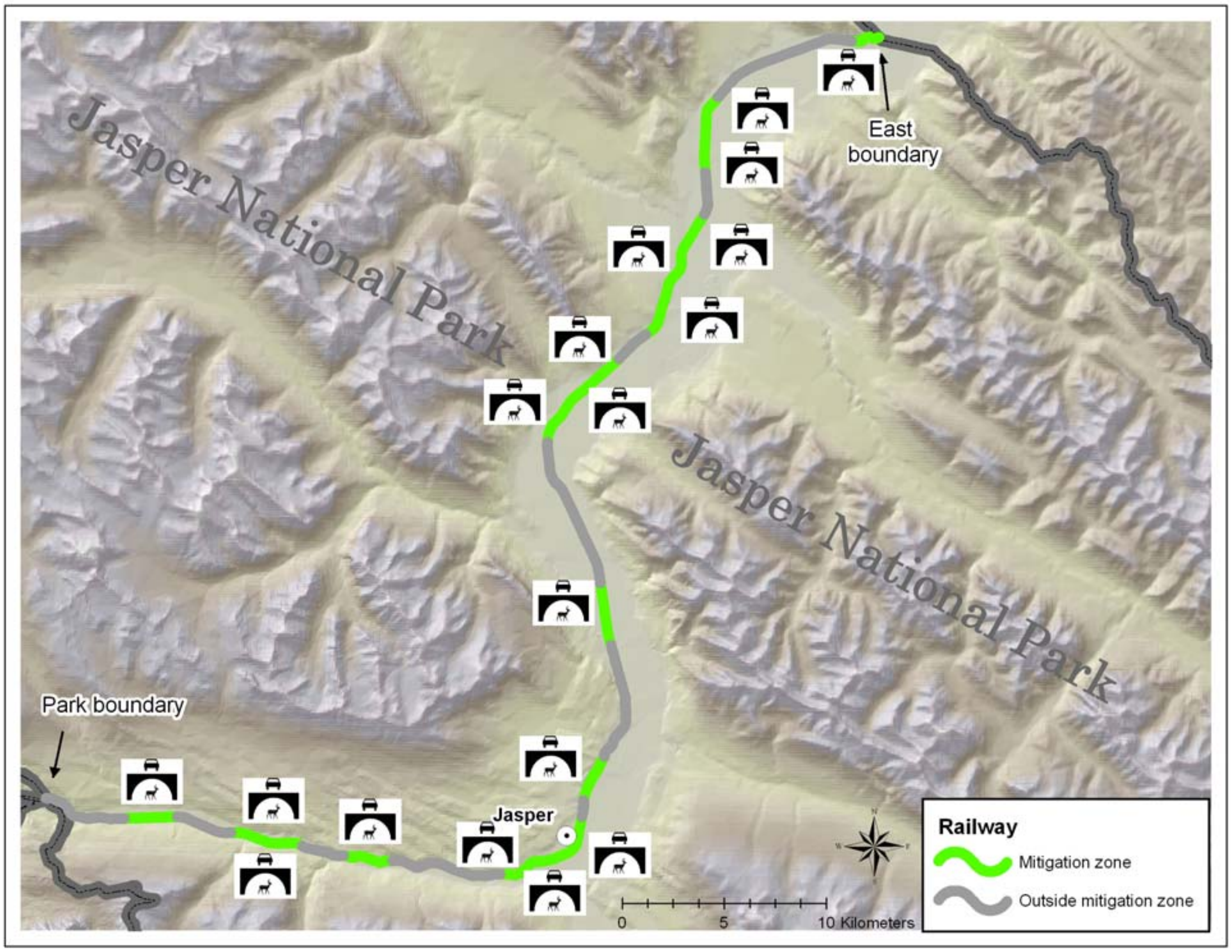

Figure 50. The mitigation zones and the suggested type and number of safe crossing opportunities per mitigation zone for the railroad through JNP.

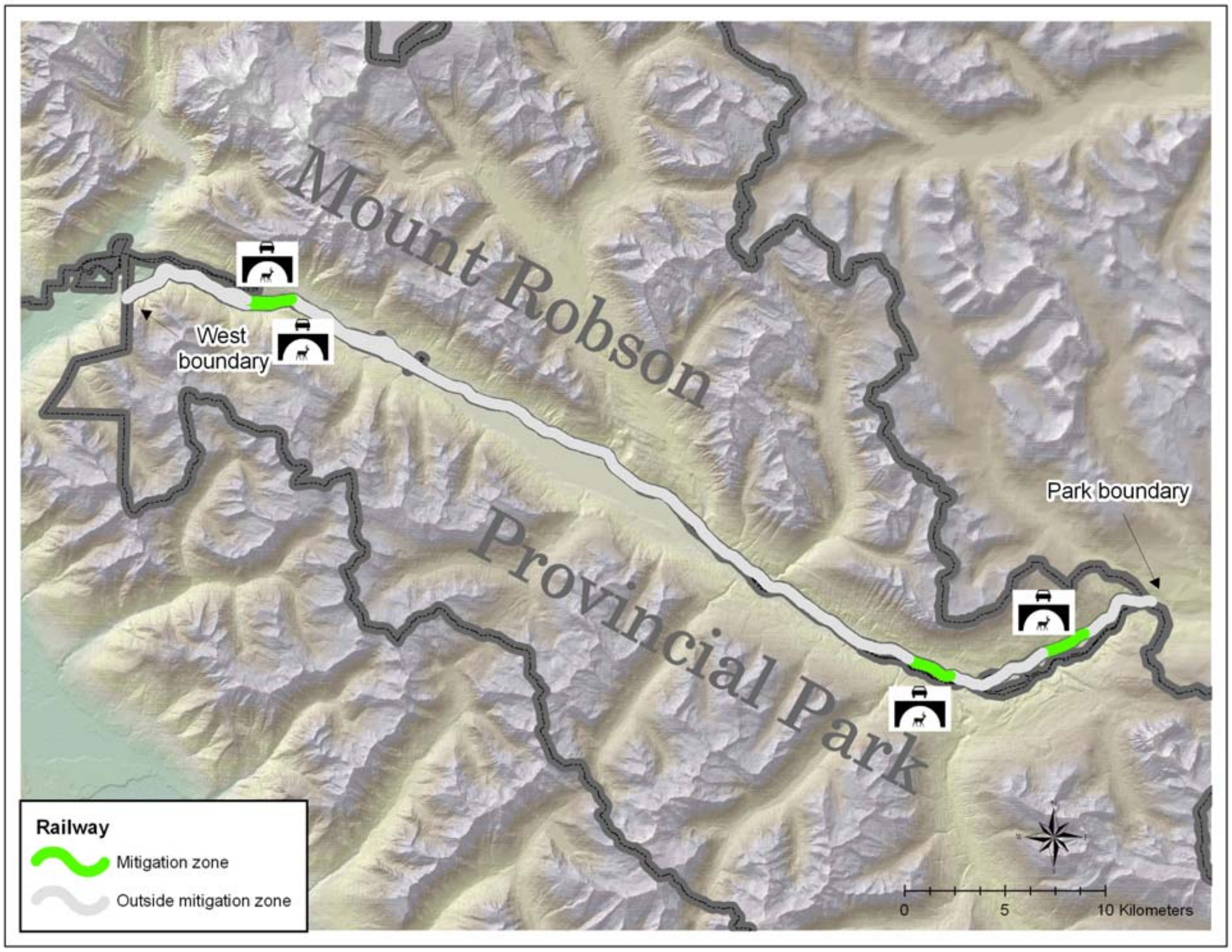

Figure 51. The mitigation zones and the suggested type and number of safe crossing opportunities per mitigation zone for the railroad (Albreda and Robson section) through MRPP.

The authors of this report do not think that small and medium sized mammals were reliably reported, either dead or alive. Using minimal data appears 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), the diameter of the home range of the species concerned (Appendix I) may serve as an indication of the spacing between such crossing opportunities. 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.

8. QUICK ASSESSMENT OF THE POTENTIAL IMPACT OF ROAD AND RAILROAD MORTALITY ON POPULATION PERSISTENCE OF THE FOCAL SPECIES IN JNP AND MRPP

Note: The actual contents of this chapter has been removed to Appendix J.

The long-term biological significance of kills by vehicles and trains in JNP and MRPP depends on each species' resilience, including potential and existing population size. Resilience is a function of: 1) individual behaviour and plasticity in dealing with transportation infrastructure; 2) the local population's ability to compensate for unnatural sources of mortality such as direct road and railroad mortality; and 3) the frequency and magnitude of immigration from nearby populations outside JNP and MRPP (Weaver et al., 1996). Local population size is a reflection of habitat availability and habitat suitability (influenced by natural disturbance and variability and human-induced change), as well as population dynamics (births and deaths from natural and human causes along with dispersal from and immigration to the local population). In JNP and MRPP, the coyote is an example of a carnivore with high resilience and large potential population size while the wolverine is an example of a carnivore with low resilience and low potential population size. Because of their lower resilience, road and railway mortality is more likely to affect the population viability of wolverine than for coyote. The resilience of the other carnivore species may fall between these two extremes.

Population Viability Analysis (PVA) is an established tool used to identify threats faced by a species and evaluate the likelihood it will persist for a given time into the future under different management approaches (Boyce, 1992; Akcakaya, 2000; Chisholm & Wintle, 2007). Formal population viability assessment methods require extensive, high-quality data on population dynamics, usually obtained from long-term studies (Flather et al., 2011). Unfortunately, acquiring reliable information about population status and trends of low-density and secretive animals such as carnivores is expensive and difficult (Mattson et al., 1996). Instead a quick-scan approach was chosen to obtain insight in the population persistence of the focal species in JNP and MRPP and to evaluate the potential impact of direct road and railroad mortality on population persistence. This analysis is included in Appendix J.

Better information on population trends and dynamics and appropriate funding is needed to calculate more precise estimates of the population implications of road and railway mortality in MRPP and JNP. Formal population viability analyses can also take the potential presence of populations in the areas adjacent to JNP and MRPP into account and the connectivity between these populations and those inside JNP and MRPP.

9. COST-BENEFIT ANALYSES

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in Hedlund et al. 2004, Knapp et al. 2004, Huijser et al. 2008). Examples include warning signs that alert drivers to potential animal crossings, wildlife warning reflectors or mirrors (e.g., Reeve and Anderson 1993, Ujvári et al. 1998), wildlife fences (Clevenger et al., 2001), and animal detection systems (Huijser et al., 2006b). However, the effectiveness and costs of these mitigation measures vary greatly. When the effectiveness is evaluated in relation to the costs for the mitigation measure, important insight is obtained regarding which mitigation measures may be preferred, at least from a monetary perspective. For the purpose of this report the researchers conducted cost-benefit analyses for four different types and combinations of mitigation measures for the sections of Hwy 16 through JNP and MRPP. The railroad sections through JNP and MRPP were not included in this analyses as they researchers had no data available with regard to the costs of wildlife-train collisions.

The types and combinations of mitigation measures evaluated for this report included:

- Animal detection system
- Fence, gap (once every 2 km), animal detection system in gap, jump-outs
- Fence, under- and overpass (underpass once every 2 km, overpass once every 24 km), jump-outs
- Fence, under pass (once every 2 km), jump-outs

For details on the effectiveness and estimated costs of the mitigation measures per 0.62 mile (1 km) per year and other methodological aspects of the cost-benefit analyses see Huijser et al. (2009). This publication also provides a rationale for the estimated costs associated with each deer-vehicle (US$ 6,617), elk-vehicle (US$ 17,483), and moose-vehicle collision (US $30,760). The cost for wildlife-vehicle collisions is expressed in US dollars per year per 0.62 mi (1 km).

For Hwy 16 through JNP the researchers used the average annual recorded road mortality data reported within 200 m from Hwy 16 based on a ten year period (1 January 2000 through 31 December 2009). For Hwy 16 through MRPP the researchers used the average annual recorded road mortality data based on a 12 year period (1 January 1998 through 31 December 2009). The researchers categorized all focal species and selected other species into three groups based on their similarity in body size and weight to deer, elk, and moose (Table 17). For example, if the recorded data show that a wolf was hit, the researchers assumed the damage and the associated costs to be similar to having hit a deer.

Table 17. The categorization of the focal species and selected other species into three groups based on their similarity in body size and weight to deer, elk, and moose. Species that were considered too small in body size and too light in body weight to cause substantial damage to a vehicle in case of a collision were assigned into the "none" category.

Species name	Code	Deer	Elk	Moose	None
Focal species					
Fisher (*Martes pennanti*)	FISH				X
Wolverine (*Gulo gulo)*	WOLV	X			
Bobcat (*Lynx rufus)*	BOBC				X
Canada lynx (*Lynx canadensis)*	LYNX	X			
Cougar (*Puma concolor)*	COUG	X			
Red fox (*Vulpes vulpes*)	REFO, FOX				X
Coyote (*Canis latrans)*	COYO				X
Wolf (*Canis lupus*)	WOLF	X			
Black bear (*Ursus americanus)*	BLAC, BEAR		X		
Grizzly bear (*Ursus arctos*)	GRIZ, BEAR		X		
Woodland caribou (*Rangifer tarandus caribou*)	CARI		X		
Selected other species					
White-tailed deer (*Odocoileus virginianus)*	WHIT, DEER	X			
Mule deer (*Odocoileus hemionus)*	MULE, DEER	X			
Elk (*Cervus canadensis*)	ELK		X		
Moose (*Alces alces)*	MOOS			X	
Mountain goat (*Oreamnos americanus*)	GOAT	X			
Bighorn sheep (*Ovis canadensis*)	SHEE	X			

Figure 53 and 54 show for which road sections the number of recorded wildlife-vehicle collisions was high enough to meet or exceed thresholds for the implementation of four different types of mitigation measures. Hwy 16 through JNP has four road segments where the threshold values for all four mitigation measures were met or exceeded. Hwy 16 through MRPP does not have any road segments where any of the four threshold values for the different mitigation measures are met or exceeded. However, not meeting or exceeding the threshold values anywhere along Hwy 16 in MRPP may be mostly related to the search and reporting effort that was believed to be relatively low for this road section (see Chapter 8).

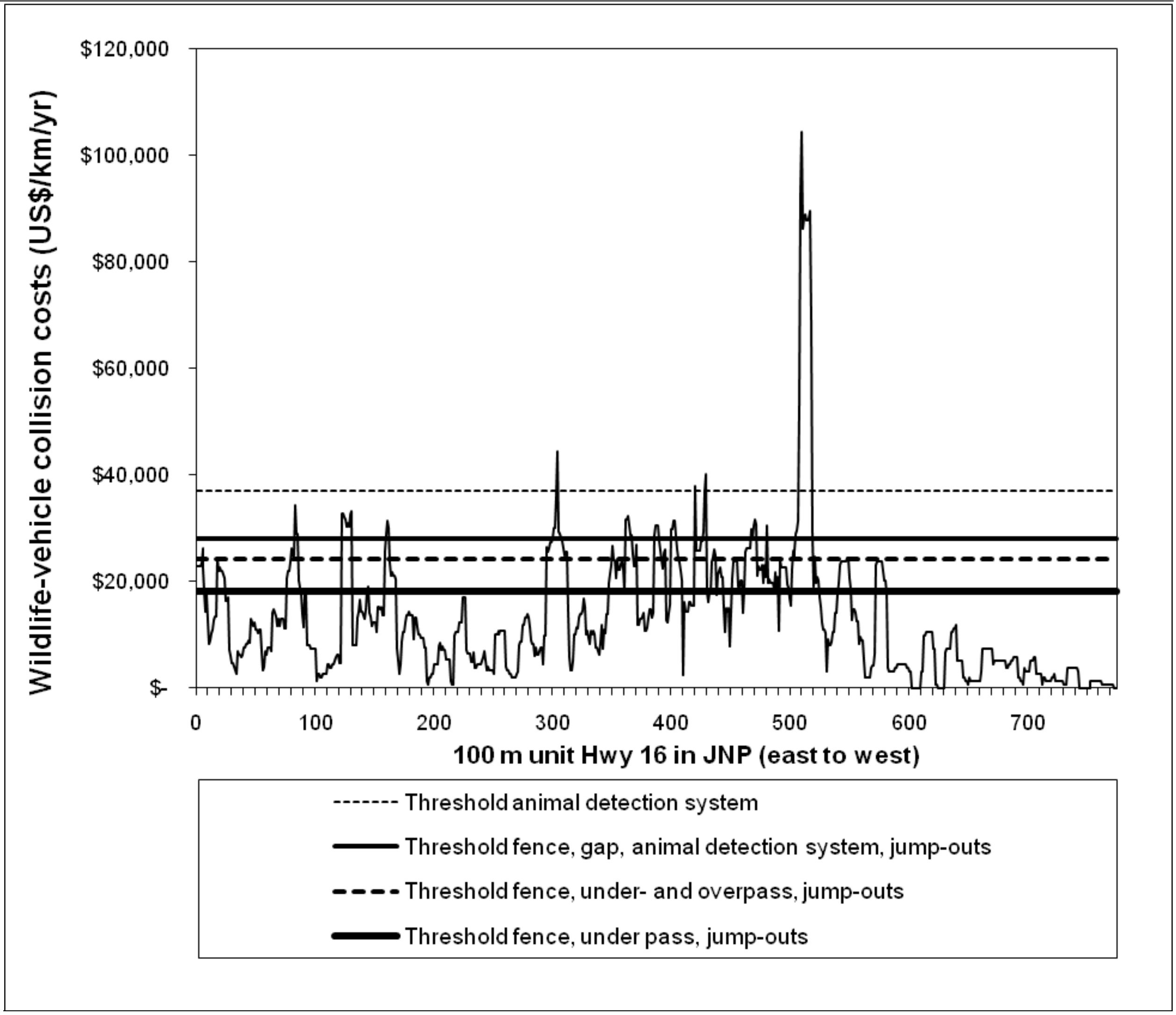

Figure 52. Hwy 16 through JNP from east to west. The estimated costs (in 2007 US$) associated with wildlife-vehicle collisions per year (average 1 January 2000 – 31 December 2009), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 100 m long road section concerned and adjacent 100 m units were summed to estimate the costs per kilometer.

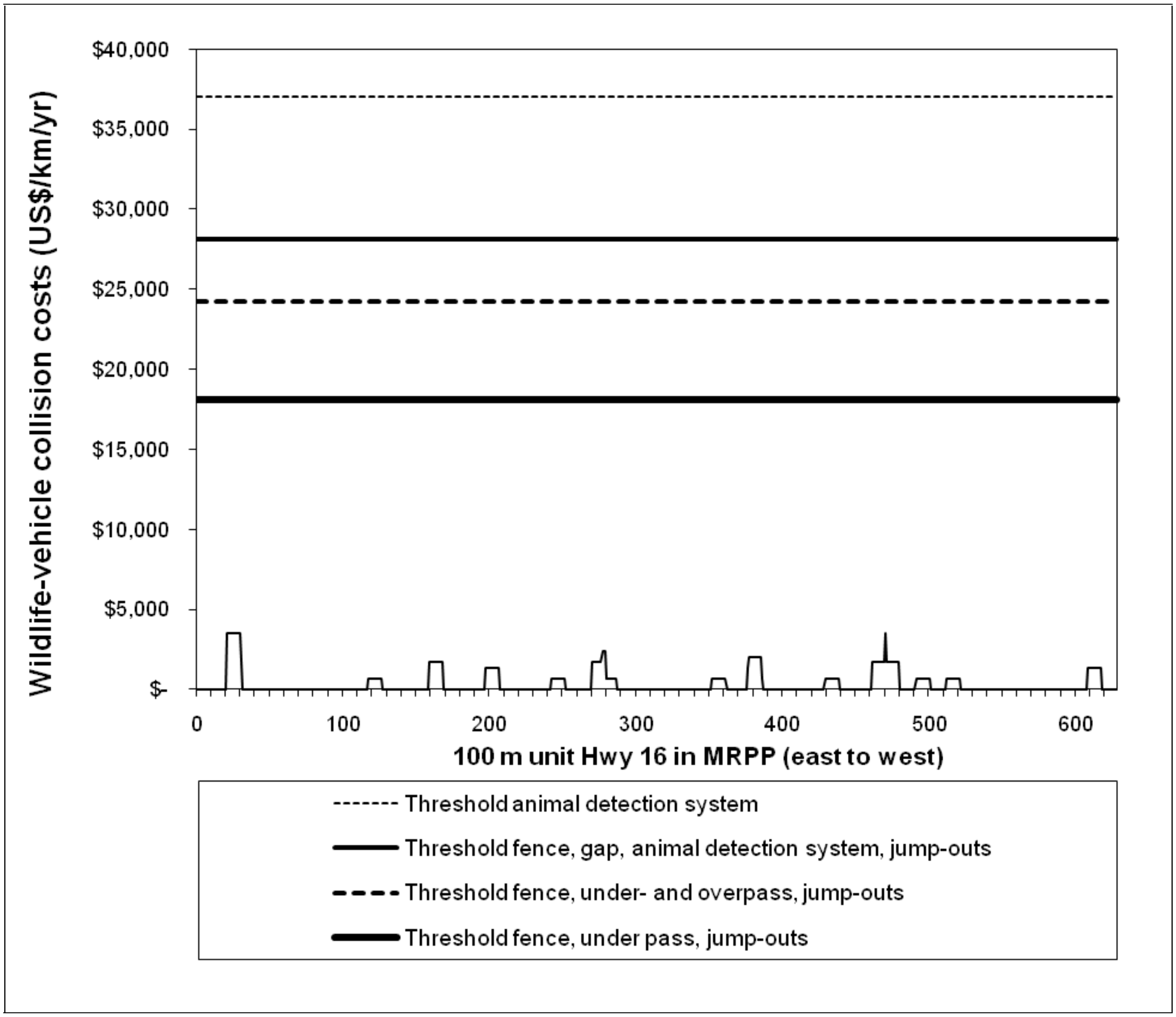

Figure 53. Hwy 16 through JNP from east to west. The estimated costs (in 2007 US$) associated with wildlife-vehicle collisions per year (average 1 January 2000 – 31 December 2009), and the threshold values (at 3% discount rate) that need to be met in order to have the benefits of individual mitigation measures exceed the costs over a 75 year long time period. Note that the costs at each 100 m long road section concerned and adjacent 100 m units were summed to estimate the costs per kilometer.

The cost-benefit analysis is relatively conservative and does not include passive use values. For a full understanding what is and what is not included in the cost-benefit analyses and how the analyses were conducted see Huijser et al. (2009). Furthermore, the costs and benefits are expressed in 2007 US$ and the costs associated with deer-vehicle collisions and with mitigation measures change continuously and may also vary between geographic regions. Therefore the cost-benefit analyses should be regarded as indicative. Note that the cost-benefit analyses do not include all parameters that should be considered when making a decision on the implementation of potential mitigation measures. The researchers strongly advise to use the cost-benefit analyses as a decision support tool but also urge users to recognize that it is only one of the factors that may or should be considered in the decision making process.

10. RECOMMENDED DATA COLLECTION

10.1 Introduction

The wildlife mortality data collection program in JNP and MRPP, and the wildlife observation data collection program in JNP have been extremely important to this project. Long term datasets such as the ones for JNP allowed the researchers to have a relatively robust process in identifying and prioritizing road and railroad sections that may require mitigation measures, including safe crossing opportunities for wildlife. It also allowed for recommendations with regard to the target species for the mitigation measures, particularly for the safe crossing opportunities. The long time period for which data were available for in JNP 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 Road and Railroad Mortality Data

- Continue to collect road and railroad mortality data. Long term datasets are extremely important as they reflect the long term dynamics in ecosystem. The data collection program was already initiated in the 1950s for JNP. However, it appears that the data collection program in MRPP is much younger and is in greater need than JNP for such long term monitoring.
- Increase the search and reporting effort for road and railroad mortalities in MRPP. A subjective interpretation of the data suggests that only a small fraction of the number of road and railroad mortalities in MRPP is currently reported. While having a consistent search and reporting effort is important, the researchers feel that the search and reporting effort in MRPP may be too low to produce useful results without applying large corrections to compensate for likely underreporting. The available data for the focal species are very low for MRPP, making the identification and prioritization of road sections that may need mitigation measures not very robust.
- Collect more spatially precise data in MRPP, preferably based on a coordinate system, preferably using GPS. Alternatively a road based kilometer system could be used, but then there should preferably be hectometer poles (every 100 m) rather than the current kilometer poles that are 5 kilometers apart. The current location description system is based on road segments of variable length. This not only results in spatial imprecision, but also in inconsistent spatial accuracy because of the variable length of the road segments.
- Specify the species for bears along Hwy 16 in Mt Robson. Now it is simply “bear” that is reported which could relate to either black bear or grizzly bear. For the purpose of this report the researchers assumed these observations all related to black bears.

- Consistently fill out on which road or railroad an animal was struck, or enter “unknown road or railroad” or “unknown road” or unknown railroad”. Currently many observations from JNP do not have the road name specified.
- Continue to collect data on the gender and age of the individuals reported dead. Currently this type of data is collected in JNP, but not in MRPP. Having better insight in the population structure and which age and gender categories are hit by vehicles or trains allows for better population viability modeling in the future.

10.3 Live Observations

- Continue to collect observations of animals seen alive in JNP and initiate a program to collect such data in MRPP. One may consider a specific monitoring schedule to ensure consistent search and reporting effort along the entire length of Hwy 16 instead of relying on the current data from JNP which are mostly incidental observations and that are likely to have greater search and reporting effort east of Jasper than west of Jasper. Observations of live animals are important as they indicate where most animals are near the road or railroad and that is important when deciding on both the location of safe crossing opportunities as well as the species that these safe crossing opportunities should be designed for. Note that locations where animals are killed by vehicles or trains are not necessarily the same locations where they cross the road successfully.
- Initiate studies that aim to provide good population estimates for the focal species, preferably for each of the three areas used for the population viability analyses. While local and regional experts had some data available for some of the focal species population size estimates for most of the focal species were obtained through home range estimates from the literature which are not necessarily very precise.
- Continue to collect data on the gender and age of the individuals reported alive, if possible. Currently this type of data is collected in JNP, but not in MRPP. Having better insight in the population structure allows for better population viability modeling in the future.
- Collect data on the population size and structure for the focal species in the areas adjacent to JNP and MRPP and also collect data on the connectivity between these populations and the network population inside JNP and MRPP.
- Collect data on road and railroad crossing frequency for the focal species and selected other species (e.g. through GPS collar studies, snow tracking). These types of data may provide a reference for the barrier effect of the road or railroad before the implementation of mitigation measures. Once the mitigation measures have been implemented these studies can be repeated, and, combined with the references, they will allow for an assessment of the effectiveness of the safe crossing opportunities. When GPS collars are used these studies can also show whether individuals were able to maintain their home range on both sides of the road or railroad, whether they changed how frequently they cross the road or railroad, and whether the (limited) crossing opportunities may have caused the individual to change the shape of its home range.

10.4 Future Analyses

- In contract to the quick assessment in Appendix J formal population viability analyses for the focal species require detailed data on population trends and dynamics. Such more advanced analyses allow for a comparison of different scenarios, for example, scenarios in which the number, location, type, and dimensions of safe crossing opportunities vary, and each scenario results in an estimate for the population survival probability of the selected species.
- If mitigation measures are implemented it is advisable to identify success parameters and have target values for the effectiveness of the measures. Highway or railroad mitigation measures typically have two different types of success parameters: one is related to human safety (collision reduction) and the other to habitat connectivity (animal movements across the road). With regard to collision reduction it is important to have data collection programs for crash data and/or carcass removal data. It is important that the search and reporting effort remains consistent before and after implementation of the mitigation measures. In addition to the before-after comparison it is advisable to also conduct a control-impact comparison for road sections where mitigation measures have been implemented (impact or treatment) and road sections that were unaltered (control). If the control and impact areas are relatively close together they can help estimate the potential effect of population fluctuations on the number of wildlife-vehicle collisions. If possible, species specific population estimates (absolute or relative) may be considered to correct for the influence of changing population sizes on the number of wildlife-vehicle collisions. With regard to animal movements across the road it is advisable to measure the use of the safe crossing opportunities by wildlife. One may have data on how many animals used to cross the road (e.g. through tracking beds alongside the road) or how frequently individuals used to cross the road (e.g. radiotelemetery data) before the mitigation measures were implemented. These historical data can help provide a reference or target value for the wildlife use of the crossing structures. Perhaps the best way to evaluate the effectiveness of the mitigation measures related to animal movements is to measure the use of the structures and incorporate that in population viability analyses (before and after the mitigation measures are implemented).

11. CONCLUSIONS

The wildlife mortality data collection program in Jasper National Park (JNP) and Mount Robson Provincial Park (MRPP), and the wildlife observation data collection program in JNP resulted in data that made this project possible in the first place. However, the researchers found there to be likely problems with the search and reporting efforts for wildlife-vehicle collisions through animal carcass data. Underreporting for wildlife-vehicle collisions along Hwy 16 and the railroad through MRPP appears to be a problem. While underreporting occurs almost everywhere and is not necessarily a problem as long as the search and reporting effort is consistent, the researchers are of the opinion that the search and reporting effort in MRPP may be too low to produce useful results without applying large and potentially inaccurate corrections to compensate for likely underreporting.

Because the search and reporting effort appeared to vary substantially between JNP and MRPP and also between Hwy 16 and the railroad, the researchers conducted separate analyses to identify and prioritize the road and railroad sections in the two parks for the potential implementation of mitigation measures. The mitigation measures are aimed at reducing direct mortality for the focal species (carnivores and caribou) and to allow for safe crossing opportunities for the focal species and selected other species (carnivores and ungulates). The researchers are of the opinion that the identification and prioritization of road and railroad sections that may qualify for mitigation measures was relatively robust for Hwy 16 and the railroad through JNP. However, the identification and prioritization of road and railroad sections through MRPP is likely not very robust because of the scarcity of the data.

Based on the available data the researchers calculated that at an average of 19 carnivores or caribou and 131 ungulates (excluding caribou) per year are reported killed by vehicles or trains along Hwy 16 or the railroad through JNP and MRPP. The mortality data for the focal species were used to identify mortality clusters. The mortality clusters were ranked based on the average number of focal species reported per 100 m road or railroad length in a mortality cluster. The most robust mitigation measure to keep wildlife from entering the road is wildlife fencing. However, if only the wildlife mortality clusters are fenced, the animals will likely walk towards the end of the fence and cross the road at the fence end. This would result in a shift in location of the mortality rather than a substantial reduction. Therefore 1 kilometer buffer zones were projected from either end of a mortality cluster. The 1 kilometer distance is consistent with the diameter of the home range for a white-tailed deer, but the researchers recognize that other species have much greater home ranges and that the fence ends may still be within reach.

Fences alone increase the barrier effect of the road or railroad and should not be implemented without also providing for safe crossing opportunities. The most robust safe crossing opportunities are wildlife underpasses and overpasses. The location for these safe crossing opportunities should not be based solely on the locations where animals have been found dead as there may be other locations where they cross the road successfully. These latter locations should not be accidentally blocked by erecting a barrier such as a fence. Therefore the placement of safe crossing opportunities should preferably be based on observations of both dead animals and animals seen alive along roads or railroads. This not only provides better information about the best locations for safe crossing opportunities, but it also provides information on the species that the safe crossing opportunities should be designed for.

Based on a quick assessment of the population persistence for the focal species the researchers conclude that the wolf seems to be especially vulnerable if the combined area of JNP and MRPP is considered an ‘island’ with a population or network population that is isolated from populations that may be present in the surrounding areas. Furthermore, direct road and railroad mortality appears to be relatively high for wolf compared to the number of reproductive units and population size. Fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou may or may not have persistent populations in JNP and MRPP depending on the barrier effect of Hwy 16 and Hwy 93 and estimates one chooses to accept for population densities and the percentage of reproductive units in the population. The population persistence of the species listed above may well depend on the presence, size, and connectivity with populations in the areas adjacent to JNP and MRPP. One could argue that any road or railroad mortality that occurs would be undesirable for these species and that it further threatens their population persistence within the two parks. This could provide a framework, rationale or justification to implement mitigation measures along the road and railroad for these species. Coyote and black bear are most likely to have persistent populations in JNP and MRPP and may not be affected very much by direct road and railroad mortality. Better information on population trends and dynamics in JNP and MRPP will be needed to generate more precise estimates of the population sizes for the focal species and the potential impact of road and railway mortality on population survival probability. For this reason, future monitoring of population trends and dynamics should focus on species with the highest risk: wolf, fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou.

The researchers suggest large overspan bridges and large mammal underpasses for most mitigation zones, and wildlife overpasses for other mitigation zones where grizzly bears have been observed most frequently along the road or railroad. A cost-benefit analyses for four different types and combinations of mitigation measures, including wildlife fencing, underpasses, overpasses, and animal detection systems, showed that there are a number of road sections along Hwy 16 in JNP where mitigation measures may generate economic benefits in excess of costs. There are no such road sections along Hwy 16 through MRPP though. However, this is most likely related to the scarcity of the data for this road section.

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13. APPENDIX A: ROAD AND RAILROAD MORTALITIES ALONG ALL ROADS THROUGH JNP AND MRPP

This Appendix has 5 sections:

1. Legend for the abbreviation of the species for all JNP data.
2. Road mortalities (all roads) through JNP (August 1951 through December 2009).
3. Road mortalities (Hwy 16 only) through MRPP (January 1998 through December 2009).
4. Railroad mortalities through JNP (October 1952 through December 2009).
5. Railroad mortalities through MRPP (November 1997 through October 2010).

A1. Legend for the abbreviation of the species for the JNP data.

Species_code	Species_common_name	Species_scientific_name
ACCI	UNIDENTIFIED ACCIPITER	
ALFL	FLYCATCHER, ALDER	Empidonax alnorum Brewster
AMGO	GOLDFINCH, AMERICAN	Carduelis tristis (Linnaeus)
AMRE	REDSTART, AMERICAN	Setophaga ruticilla (Linnaeus)
AMWI	WIGEON, AMERICAN	Anas americana Gmelin
ARLO	LOON, ARCTIC	Gavia arctica (Linnaeus)
BAEA	EAGLE, BALD	Haliaeetus leucocephalus (Linnaeus)
BAGO	GOLDENEYE, BARROW'S	Bucephala islandica (Gmelin)
BAOW	OWL, BARRED	Strix varia Barton
BAPI	PIGEON, BAND-TAILED	Columba fasciata Say
BASA	SANDPIPER, BAIRD'S	Calidris bairdii (Coues)
BAT	BAT, UNKNOWN SPECIES	
BAWA	WARBLER, BAY-BREASTED	Dendroica castanea (Wilson)
BCCH	CHICKADEE, BLACK-CAPPED	Parus atricapillus Linnaeus
BEAR	BEAR, UNKNOWN SPECIES	
BEAV	BEAVER, AMERICAN	Castor canadensis Kuhl
BEKI	KINGFISHER, BELTED	Ceryle alcyon (Linnaeus)
BHGR	GROSBEAK, BLACK-HEADED	Pheucticus melanocephalus (Swainson)
BIBA	BAT, BIG BROWN	Eptesicus fuscus (Palisot de Beauvois)
BIRD	BIRD, UNKNOWN SPECIES	
BISO	BISON, UNKNOWN SPECIES	

BKSW	SWALLOW, BANK	Riparia riparia (Linnaeus)
BLAC	BEAR, AMERICAN BLACK	Ursus americanus Pallas
BLCU	BLACK-BILLED CUCKOO	Coccyzus erythropthalmus (Wilson)
BLGR	GROUSE, BLUE	Dendragapus obscurus (Say)
BLMA	MAGPIE, BLACK-BILLED	Pica pica (Linnaeus)
BLPL	PLOVER, BLACK-BELLIED	Pluvialis squatarola (Linnaeus)
BLSW	SWIFT, BLACK	Cypseloides niger (Gmelin)
BLTE	TEAL, BLUE-WINGED	Anas discors Linnaeus
BLTN	TERN, BLACK	Chlidonias niger (Linnaeus)
BLWO	WOODPECKER, BLACK-BACKED	Picoides arcticus (Swainson)
BNSW	SWALLOW, BARN	Hirundo rustica Linnaeus
BOBC	BOBCAT	Lynx Rufus (Schreber)
BOCH	CHICKADEE, BOREAL	Parus hudsonicus Forster
BOFR	BOREAL CHORUS FROG	Pseudacris triseriata
BOGU	GULL, BONAPARTE'S	Larus philadelphia (Ord)
BOOW	OWL, BOREAL	Aegolius funereus (Linnaeus)
BOWA	WAXWING, BOHEMIAN	Bombycilla garrulus (Linnaeus)
BPWA	WARBLER, BLACKPOLL	Dendroica striata (Forster)
BRAN	BRANT	Branta bernicla (Linnaeus)
BRBL	BLACKBIRD, BREWER'S	Euphagus cyanocephalus (Wagler)
BRCO	COWBIRD, BROWN-HEADED	Molothrus ater (Boddaert)
BRCR	CREEPER, BROWN	Certhia americana Bonaparte
BRSP	SPARROW, BREWER'S	Spizella breweri Cassin
BUFF	BUFFLEHEAD	Bucephala albeola (Linnaeus)
BUOW	OWL, BURROWING	Athene cunicularia (Molina)
BURA	RAT, BUSHY-TAILED WOOD	Neotoma cinerea (Ord)
BUSA	SANDPIPER, BUFF-BREASTED	Tryngites subruficollis (Vieillot)
BWWA	WARBLER, BLACK-AND-WHITE	Mniotilta varia (Linnaeus)
CAFI	FINCH, CASSIN'S	Carpodacus cassinii Baird
CAGO	GOOSE, CANADA	Branta canadensis (Linnaeus)
CAGU	GULL, CALIFORNIA	Larus californicus Lawrence
CAHU	HUMMINGBIRD, CALLIOPE	Stellula calliope (Gould)
CANV	CANVASBACK	Aythya valisineria (Wilson)

CARI	CARIBOU, WOODLAND	Rangifer tarandus caribou (Gmelin)
CAWA	WARBLER, CANADA	Wilsonia canadensis (Linnaeus)
CEWA	WAXWING, CEDAR	Bombycilla cedrorum Vieillot
CHSP	SPARROW, CHIPPING	Spizella passerina (Bechstein)
CITE	TEAL, CINNAMON	Anas cyanoptera Vieillot
CLNU	NUTCRACKER, CLARK'S	Nucifraga columbiana (Wilson)
CLSP	SPARROW, CLAY-COLORED	Spizella pallida (Swainson)
CLSW	SWALLOW, CLIFF	Hirundo pyrrhonota Vieillot
CMWA	WARBLER, CAPE MAY	Dendroica tigrina (Gmelin)
COCR	CROW, AMERICAN	Corvus brachyrhynchos Brehm
COFL	FLICKER, NORTHERN	Colaptes auratus (Linnaeus)
COGO	GOLDENEYE, COMMON	Bucephala clangula (Linnaeus)
COGR	GRACKLE, COMMON	Quiscalus quiscula (Linnaeus)
COHA	HAWK, COOPER'S	Accipiter cooperii (Bonaparte)
COLO	LOON, COMMON	Gavia immer (Br nnich)
COME	MERGANSER, COMMON	Mergus merganser Linnaeus
CONI	NIGHTHAWK, COMMON	Chordeiles minor (Foster)
COOT	COOT, AMERICAN	Fulica americana Gmelin
CORA	RAVEN, COMMON	Corvus corax Linnaeus
CORE	REDPOLL, COMMON	Carduelis flammea (Linnaeus)
COSN	SNIPE, COMMON	Gallinago gallinago (Linnaeus)
COSQ	SQUIRREL, COLUMBIAN GROUN	Spermophilus columbianus (Ord)
COTE	TERN, COMMON	Sterna hirundo Linnaeus
COUG	COUGAR	Felis concolor Linnaeus
COYO	COYOTE	Canis latrans Say
CRFO	FOX, CROSS	
CROS	CROSSBILL, UNKNOWN SPECIES	
DAJU	JUNCO, DARK-EYED	Junco hyemalis (Linnaeus)
DEER	DEER, UNKNOWN SPECIES	
DEMO	MOUSE, DEER	Peromyscus maniculatus (Wagner)
DIPP	DIPPER, AMERICAN	Cinclus mexicanus Swainson
DOCO	CORMORANT, DOUBLE-CRESTED	Phalacrocorax auritus (Lesson)
DOWO	WOODPECKER, DOWNY	Picoides pubescens (Linnaeus)

DUCK	DUCK, UNKNOWN SPECIES	
DUFL	FLYCATCHER, DUSKY	Empidonax oberholseri Phillips
DUNL	DUNLIN	Calidris alpina (Linnaeus)
DUSH	SHREW, DUSKY	Sorex obscurus Merriam
EAGL	EAGLE, UNKNOWN SPECIES	
EAGR	GREBE, EARED	Podiceps nigricollis (C.L. Brehm)
EAKI	KINGBIRD, EASTERN	Tyrannus tyrannus (Linnaeus)
EAPH	PHOEBE, EASTERN	Sayornis phoebe (Latham)
ELK	ELK, AMERICAN	Cervus elaphus Linnaeus
ERMI	ERMINE	Mustela erminea Linnaeus
ESCR	CURLEW, ESKIMO	Numenius borealis (Forster)
EUWI	WIGEON, EURASIAN	Anas penelope Linnaeus
EVGR	GROSBEAK, EVENING	Coccothraustes vespertinus (Cooper)
FALC	FALCON, UNKNOWN SPECIES	
FEHA	HAWK, FERRUGINOUS	Buteo regalis (Gray)
FISH	FISHER	Martes pennanti (Erxleben)
FLSQ	SQUIRREL, NORTHERN FLYING	Glaucomys sabrinus (Shaw)
FOSP	SPARROW, FOX	Passerella iliaca (Merrem)
FOTE	TERN, FORSTER'S	Sterna forsteri Nuttall
FOX	FOX, UNKNOWN SPECIES	
FRGU	GULL, FRANKLIN'S	Larus pipixcan Wagler
GADW	GADWALL	Anas strepera Linnaeus
GAVO	VOLE, GAPPER'S RED-BACKED	Clethrionomys gapperi (Vigors)
GEES	GEESE, UNKNOWN SPECIES	
GGOW	OWL, GREAT GRAY	Strix nebulosa Foster
GHOW	OWL, GREAT HORNED	Bubo virginianus (Gmelin)
GOAT	GOAT, MOUNTAIN	Oreamnos americanus (de Blainville)
GOEA	EAGLE, GOLDEN	Aquila chrysaetos (Linnaeus)
GOKI	KINGLET, GOLDEN-CROWNED	Regulus satrapa Lichtenstein
GOPL	GOLDEN-PLOVER, LESSER	Pluvialis dominica (Moller)
GOSH	GOSHAWK, NORTHERN	Accipiter gentilis (Linnaeus)
GOSP	SPARROW, GOLDEN-CROWNED	Zonotrichia atricapilla (Gmelin)
GOSQ	SQUIRREL, GOLDEN-MANTLED	Spermophilus lateralis (Say)

GRCA	CATBIRD, GRAY	Dumetella carolinensis (Linnaeus)
GRFI	FINCH, GRAY-CROWNED ROSY	Leucosticte arctoa tephrocotis (Swaison)
GRHE	HERON, GREAT BLUE	Ardea herodias Linnaeus
GRIZ	BEAR, GRIZZLY	Ursus arctos Linnaeus
GRJA	JAY, GRAY	Perisoreus canadensis (Linnaeus)
GROU	GROUSE, UNKNOWN SPECIES	
GRPA	PARTRIDGE, GRAY	Perdix perdix (Linnaeus)
GRSC	SCAUP, GREATER	Aythya marila (Linnaeus)
GRTE	TEAL, GREEN-WINGED	Anas crecca Linnaeus
GRTH	THRUSH, GRAY-CHEEKED	Catharus minimus (Lafresnaye)
GRYE	YELLOWLEGS, GREATER	Tringa melanoleuca (Gmelin)
GYRF	GYRFALCON	Falco rusticolus Linnaeus
HADU	DUCK, HARLEQUIN	Histrionicus histrionicus (Linnaeus)
HAFL	FLYCATCHER, HAMMOND'S	Empidonax hammondii (Xantus)
HAOW	HAWK-OWL, NORTHERN	Surnia ulula (Linnaeus)
HASP	SPARROW, HARRIS'S	Zonotrichia querula (Nuttall)
HAWK	HAWK, UNKNOWN SPECIES	
HAWO	WOODPECKER, HAIRY	Picoides villosus (Linnaeus)
HEGU	GULL, HERRING	Larus argentatus Pontoppidan
HETH	THRUSH, HERMIT	Catharus guttatus (Pallas)
HEVO	VOLE, HEATHER	Phenacomys intermedius Merriam
HOFI	FINCH, HOUSE	Carpodacus mexicanus (Moller)
HOGR	GREBE, HORNED	Podiceps auritus (Linnaeus)
HOLA	LARK, HORNED	Eremophila alpestris (Linnaeus)
HOMA	MARMOT, HOARY	Marmota caligata (Eschscholtz)
HOME	MERGANSER, HOODED	Lophodytes cucullatus (Linnaeus)
HOMO	MOUSE, HOUSE	Mus musculus Linnaeus
HORE	REDPOLL, HOARY	Carduelis hornemanni (Holboll)
HOSP	SPARROW, HOUSE	Passer domesticus (Linnaeus)
KEBA	BAT, KEEN'S	Myotis keenii (Merriam)
KEST	KESTREL, AMERICAN	Falco sparverius Linnaeus
KILL	KILLDEER	Charadrius vociferus Linnaeus
LALO	LONGSPUR, LAPLAND	Calcarius lapponicus (Linnaeus)

LEBA	BAT, LONG-EARED	Myotis evotis (H.Allen)
LECH	CHIPMUNK, LEAST	Eutamias minimus (Bachman)
LEFL	FLYCATCHER, LEAST	Empidonax minimus (Baird and Baird)
LESA	SANDPIPER, LEAST	Calidris minutilla (Vieillot)
LESC	SCAUP, LESSER	Aythya affinis (Eyton)
LESP	SPARROW, LE CONTE'S	Ammodramus leconteii (Audubon)
LEWE	WEASEL, LEAST	Mustela nivalis Linnaeus
LEWO	WOODPECKER, LEWIS'S	Melanerpes lewis (Gray)
LEYE	YELLOWLEGS, LESSER	Tringa flavipes (Gmelin)
LIBA	BAT, LITTLE-BROWN	Myotis lucifugus (LeConte)
LISP	SPARROW, LINCOLN'S	Melospiza lincolnii (Audubon)
LOBA	BAT, LONG-LEGGED	Myotis volans (H.Allen)
LODO	DOWITCHER, LONG-BILLED	Limnodromus scolopaceus (Say)
LOJA	JAEGER, LONG-TAILED	Stercorarius longicaudus Vieillot
LOOW	OWL, LONG-EARED	Asio otus (Linnaeus)
LOSA	LONG TOED SALAMANDER	
LOSH	SHRIKE, LOGGERHEAD	Lanius ludovicianus (Linnaeus)
LOVO	VOLE, LONG-TAILED	Microtus longicaudus (Merriam)
LOWE	WEASEL, LONG-TAILED	Mustela frenata Lichtenstein
LOWR	WREN, MARSH	Cistothorus palustris (Wilson)
LYNX	LYNX	Lynx lynx (Linnaeus)
LZBU	BUNTING, LAZULI	Passerina amoena (Say)
MAGO	GODWIT, MARBLED	Limosa fedoa (Linnaeus)
MAHA	HARRIER, NORTHERN	Circus cyaneus (Linnaeus)
MALL	MALLARD	Anas platyrhynchos Linnaeus
MART	MARTEN, AMERICAN	Martes americana (Turton)
MASH	SHREW, MASKED	Sorex cinereus Kerr
MAWA	WARBLER, MAGNOLIA	Dendroica magnolia (Wilson)
MCWA	WARBLER, MACGILLIVRAY'S	Oporornis tolmiei (Townsend)
MEGU	GULL, MEW	Larus canus Linnaeus
MERL	MERLIN	Falco columbarius Linnaeus
MEVO	VOLE, MEADOW	Microtus pennsylvanicus (Ord)
MINK	MINK, AMERICAN	Mustela vison Schreber

MOBL	BLUEBIRD, MOUNTAIN	Sialia currucoides (Bechstein)
MOCH	CHICKADEE, MOUNTAIN	Parus gambeli Ridgway
MODO	DOVE, MOURNING	Zenaida macroura (Linnaeus)
MOOS	MOOSE	Alces alces (Linnaeus)
MULE	DEER, MULE	Odocoileus hemionus (Rafinesque)
MUSK	MUSKRAT	Ondatra zibethicus (Linnaeus)
NOLE	LEMMING, NORTHERN BOG	Synaptomys borealis (Richardson)
NOOR	ORIOLE, NORTHERN	Icterus galbula (Linnaeus)
NOSH	SHRIKE, NORTHERN	Lanius excubitor Linnaeus
NOTO	NORTHERN TOAD	
NOWA	WATERTHRUSH, NORTHERN	Seiurus noveboracensis (Gmelin)
NOWO	WOODPECKER, THREE-TOED	Picoides tridactylus (Linnaeus)
OLDS	OLDSQUAW	Clangula hyemalis (Linnaeus)
OLFL	FLYCATCHER, OLIVE-SIDED	Contopus borealis (Swaison)
ORWA	WARBLER, ORANGE-CROWNED	Vermivora celata (Say)
OSPR	OSPREY	Pandion haliaetus (Linnaeus)
OTTE	OTTER, RIVER	Lontra canadensis (Schreber)
OVEN	OVENBIRD	Seiurus aurocapillus (Linnaeus)
OWL	OWL, UNKNOWN SPECIES	
PAJA	JAEGER, PARASITIC	Stercorarius parasiticus (Linnaeus)
PAWA	WARBLER, PALM	Dendroica palmarum (Gmelin)
PBGR	GREBE, PIED-BILLED	Podilymbus podiceps (Linnaeus)
PEFA	FALCON, PEREGRINE	Falco peregrinus Tunstall
PESA	SANDPIPER, PECTORAL	Calidris melanotos (Vieillot)
PHVI	VIREO, PHILADELPHIA	Vireo philadelphicus (Cassin)
PIGR	GROSBEAK, PINE	Pinicola enucleator (Linnaeus)
PIKA	PIKA, AMERICAN	Ochotona princeps (Richardson)
PINT	PINTAIL, NORTHERN	Anas acuta Linnaeus
PISI	SISKIN, PINE	Carduelis pinus (Wilson)
PIWO	WOODPECKER, PILEATED	Dryocopus pileatus (Linnaeus)
PLSN	SNAKE, PLAINS GARTER	Thamnophis radix haydeni
PORC	PORCUPINE, AMERICAN	Erethizon dorsatum (Linnaeus)
PRFA	FALCON, PRAIRIE	Falco mexicanus Schlegel

PTAR	PTARMIGAN, UNKNOWN SPECIES	
PUFI	FINCH, PURPLE	Carpodacus purpureus (Gmelin)
PYOW	PYGMY-OWL, NORTHERN	Glaucidium gnoma Wagler
PYSH	SHREW, PIGMY	Microsorex hoyi (Baird)
RABB	RABBIT, UNKNOWN SPECIES	
REBL	BLACKBIRD, RED-WINGED	Agelaius phoeniceus (Linnaeus)
RECR	CROSSBILL, RED	Loxia curvirostra Linnaeus
REDH	REDHEAD	Aythya americana (Eyton)
REFO	FOX, RED	Vulpes vulpes (Linnaeus)
REGR	GREBE, RED-NECKED	Podiceps grisegena (Boddaert)
REHA	HAWK, RED-TAILED	Buteo jamaicensis (Gmelin)
RELO	LOON, RED THROATED	Gavia stellata (Pontoppidan)
REME	MERGANSER, RED-BREASTED	Mergus serrator Linnaeus
RENU	NUTHATCH, RED-BREASTED	Sitta canadensis Linnaeus
REPH	PHALAROPE, RED	Phalaropus fulicaria (Linnaeus)
RESN	RED SIDED GARTER SNAKE	
RESQ	SQUIRREL, AMERICAN RED	Tamiasciurus hudsonicus (Erxleben)
REVI	VIREO, RED-EYED	Vireo olivaceus (Linnaeus)
RIDU	DUCK, RING-NECKED	Aythya collaris (Donovan)
RIGU	GULL, RING-BILLED	Larus delawarensis Ord
RNPH	PHALAROPE, RED-NECKED	Phalaropus lobatus (Linnaeus)
ROBI	ROBIN, AMERICAN	Turdus migratorius Linnaeus
RODO	DOVE, ROCK	Columba livia Gmelin
ROGR	GROSBEAK, ROSE-BREASTED	Pheucticus ludovicianus (Linnaeus)
ROHA	HAWK, ROUGH-LEGGED	Buteo lagopus (Pontoppidan)
ROWR	WREN, ROCK	Salpinctes obsoletus (Say)
RTHU	HUMMINGBIRD, RUBY-THROATE	Archilochus colubris (Linnaeus)
RUBL	BLACKBIRD, RUSTY	Euphagus carolinus (Moller)
RUBO	BOA, RUBBER	Charina bottae
RUDU	DUCK, RUDDY	Oxyura jamaicensis (Gmelin)
RUGR	GROUSE, RUFFED	Bonasa umbellus (Linnaeus)
RUHU	HUMMINGBIRD, RUFOUS	Selasphorus rufus (Gmelin)
RUKI	KINGLET, RUBY-CROWNED	Regulus calendula (Linnaeus)

RWSW	SWALLOW, NORTHERN ROUGH-W	Stelgidopteryx serripennis (Audubon)
SACR	CRANE, SANDHILL	Grus canadensis (Linnaeus)
SAND	SANDERLING	Calidris alba (Pallas)
SAOW	OWL, NORTHERN SAW-WHET	Aegolius acadicus (Gmelin)
SAPH	PHOEBE, SAY'S	Sayornis says (Bonaparte)
SASP	SPARROW, SAVANNAH	Passerculus sandwichensis (Gmelin)
SEPL	PLOVER, SEMIPALMATED	Charadrius semipalmatus Bonaparte
SESA	SANDPIPER, SEMIPALMATED	Calidris pusilla (Linnaeus)
SHDO	DOWITCHER, SHORT-BILLED	Limnodromus griseus (Gmelin)
SHEE	SHEEP, BIGHORN	Ovis canadensis Shaw
SHGR	GROUSE, SHARP-TAILED	Tympanuchus phasianellus (Linnaeus)
SHHA	HAWK, SHARP-SHINNED	Accipiter striatus Vieillot
SHOV	SHOVELER, NORTHERN	Anas clypeata Linnaeus
SHOW	OWL, SHORT-EARED	Asio flammeus (Pontoppidan)
SHRE	SHREW, UNKNOWN SPECIES	
SHSP	SPARROW, SHARP-TAILED	Ammodramus caudacutus (Gmelin)
SIBA	BAT, SILVER-HAIRED	Lasionycteris noctivagans (LeConte)
SKUN	STRIPED SKUNK	Mephitis mephitis
SNBU	BUNTING, SNOW	Plectrophenax nivalis (Linnaeus)
SNGO	GOOSE, SNOW	Anser caerulescens (Linnaeus)
SNHA	HARE, SNOWSHOE	Lepus americanus Erxleben
SNOW	OWL, SNOWY	Nyctea scandiaca (Linnaeus)
SORA	SORA	Porzana carolina (Linnaeus)
SOSA	SANDPIPER, SOLITARY	Tringa solitaria Wilson
SOSP	SPARROW, SONG	Melospiza melodia (Wilson)
SOVI	VIREO, SOLITARY	Vireo solitarius (Wilson)
SPFR	SPOTTED FROG	
SPGR	GROUSE, SPRUCE	Dendragapus canadensis (Linnaeus)
SPPI	PIPIT, SPRAGUE'S	Anthus spragueii (Audubon)
SPSA	SANDPIPER, SPOTTED	Actitis macularia (Linnaeus)
STAR	STARLING, EUROPEAN	Sturnus vulgaris Linnaeus
STJA	JAY, STELLER'S	Cyanocitta stelleri (Gmelin)
STSA	SANDPIPER, STILT	Calidris himantopus (Bonaparte)

SUSC	SCOTER, SURF	Melanitta perspicillata (Linnaeus)
SWAN	SWAN, UNKNOWN SPECIES	
SWHA	HAWK, SWAINSON'S	Buteo swainsoni Bonaparte
SWSP	SPARROW, SWAMP	Melospiza georgiana (Latham)
SWTH	THRUSH, SWAINSON'S	Catharus ustulatus (Nuttall)
TEWA	WARBLER, TENNESSEE	Vermivora peregrina (Wilson)
THGU	GULL, ICELAND	Larus glaucoides Meyer
TOSO	SOLITAIRE, TOWNSEND'S	Myadestes townsendi (Audubon)
TOWA	WARBLER, TOWNSEND'S	Dendroica townsendi (Townsend)
TRSN	SWAN, TRUMPETER	Cygnus buccinator (Richardson)
TRSP	SPARROW, AMERICAN TREE	Spizella arborea (Wilson)
TRSW	SWALLOW, TREE	Tachycineta bicolor (Vieillot)
UNKN	UNKNOWN	UNKNOWN - historic data entry error
UPSA	SANDPIPER, UPLAND	Bartramia longicauda (Bechstein)
VATH	THRUSH, VARIED	Ixoreus naevius (Gmelin)
VESP	SPARROW, VESPER	Pooecetes gramineus (Gmelin)
VISW	SWALLOW, VIOLET-GREEN	Tachycineta thalassina (Swainson)
VOLE	VOLE, UNKNOWN SPECIES	
WAPI	PIPIT, WATER	Anthus spinoletta (Linnaeus)
WASH	SHREW, AMERICAN WATER	Sorex palustris Richardson
WASN	SNAKE, WANDERING GARTER	Thamnophis elegans vagrans Baird and Gira
WATA	TATTLER, WANDERING	Heteroscelus incanus (Gmelin)
WAVI	VIREO, WARBLING	Vireo gilvus (Vieillot)
WAVO	VOLE, RICHARDSON'S WATER	Arvicola richardsoni DeKay
WCSP	SPARROW, WHITE-CROWNED	Zonotrichia leucophrys (Forster)
WEAS	WEASEL, UNKNOWN SPECIES	
WEFL	FLYCATCHER, WESTERN	Empidonax difficilis Baird
WEGR	GREBE, WESTERN	Aechmophorus occidentalis (Lawrence)
WEKI	KINGBIRD, WESTERN	Tyrannus verticalis Say
WEME	MEADOWLARK, WESTERN	Sturnella neglecta Audubon
WEMO	MOUSE, WESTERN JUMPING	Zapus princeps J.A.Allen
WEPE	WOOD-PEWEE, EASTERN	Contopus virens (Linnaeus)
WESA	SANDPIPER, WESTERN	Calidris mauri (Cabanis)

WETA	TANAGER, WESTERN	Piranga ludoviciana (Wilson)
WHCR	CROSSBILL, WHITE-WINGED	Loxia leucoptera Gmelin
WHIT	DEER, WHITE-TAILED	Odocoileus virginianus (Zimmermann)
WHPE	PELICAN, AMERICAN WHITE	Pelecanus erythrorhynchos Gmelin
WHPT	PTARMIGAN, WHITE-TAILED	Lagopus leucurus (Richardson)
WHSC	SCOTER, WHITE-WINGED	Melanitta fusca (Linnaeus)
WHSN	SWAN, TUNDRA	Cygnus columbianus (Ord)
WIFL	FLYCATCHER, WILLOW	Empidonax traillii (Audubon)
WIPH	PHALAROPE, WILSON'S	Phalaropus tricolor (Vieillot)
WIPT	PTARMIGAN, WILLOW	Lagopus lagopus (Linnaeus)
WIWA	WARBLER, WILSON'S	Wilsonia pusilla (Wilson)
WIWR	WREN, WINTER	Troglodytes troglodytes (Linnaeus)
WOBU	BUFFALO, WOOD	Bison bison athabascae Rhoads
WODU	DUCK, WOOD	Aix sponsa (Linnaeus)
WOFR	WOOD FROG	Rana Sylvatica
WOLF	WOLF	Canis lupus Linnaeus
WOLV	WOLVERINE	Gulo gulo (Linnaeus)
WTSP	SPARROW, WHITE-THROATED	Zonotrichia albicollis (Gmelin)
YEBL	BLACKBIRD, YELLOW-HEADED	Xanthocephalus xanthocephalus (Bonaparte)
YECH	CHIPMUNK, YELLOW PINE	Tamias amoenus (J.A.Allen)
YELL	YELLOWTHROAT, COMMON	Geothlypis trichas (Linnaeus)
YERA	RAIL, YELLOW	Coturnicops noveboracensis (Gmelin)
YESA	SAPSUCKER, YELLOW-BELLIED	Sphyrapicus varius (Linnaeus)
YEWA	WARBLER, YELLOW	Dendroica petechia (Linnaeus)
YRWA	WARBLER, YELLOW-RUMPED	Dendroica coronata (Linnaeus)

A2. Road mortalities (all roads) through JNP (August 1951 through December 2009).

Species	Sum Of mortality_ (N)	Percentage (%)
ELK	1028	29.41
WHIT	614	17.56
MULE	582	16.65
SHEE	457	13.07
MOOS	209	5.98
COYO	206	5.89
BLAC	124	3.55
WOLF	72	2.06
GOAT	18	0.51
PORC	17	0.49
CARI	14	0.40
LYNX	14	0.40
REFO	14	0.40
DEER	13	0.37
BEAV	11	0.31
MART	10	0.29
GHOW	9	0.26
GRIZ	7	0.20
GGOW	6	0.17
OTTE	6	0.17
SNHA	5	0.14
RESQ	4	0.11
SKUN	4	0.11
WOLV	4	0.11
BOOW	3	0.09
CAGO	3	0.09
MALL	3	0.09
MINK	3	0.09
OWL	3	0.09
SHOW	3	0.09
BAOW	2	0.06
COCR	2	0.06
KEST	2	0.06
MERL	2	0.06
MUSK	2	0.06
OSPR	2	0.06
COFL	1	0.03
COGO	1	0.03
COHA	1	0.03
CONI	1	0.03
CORA	1	0.03
COSQ	1	0.03
COUG	1	0.03
FOX	1	0.03

GROU	1	0.03
LALO	1	0.03
RABB	1	0.03
RUGR	1	0.03
SAOW	1	0.03
SNBU	1	0.03
UNKN	1	0.03
WASN	1	0.03
YELL	1	0.03
YERA	1	0.03

A3. Road mortalities (Hwy 16 only) through MRPP (January 1998 through December 2009)

Species	Sum of mortality (N)	Percentage (%)
Moose (*Alces alces*)	85	46.45
Deer (*Odocoileus* spp.)	68	37.16
Bear (*Ursus* spp.)	14	7.65
Elk (*Cervus canadensis*)	6	3.28
Wolf (*Canis lupus*)	6	3.28
Coyote (*Canis latrans*)	2	1.09
Common porcupine (*Erethizon dorsatum*)	2	1.09

A4. Railroad mortalities through JNP (October 1952 through December 2009)

Species	Sum Of mortality_ (N)	Percentage (%)
ELK	506	39.38
SHEE	376	29.26
MULE	120	9.34
MOOS	88	6.85
BLAC	82	6.38
WHIT	46	3.58
WOLF	22	1.71
GRIZ	14	1.09
COYO	9	0.70
GHOW	4	0.31
GOEA	4	0.31
DEER	3	0.23
BAEA	2	0.16
BAOW	2	0.16
WOLV	2	0.16
CAGO	1	0.08
CORA	1	0.08
REFO	1	0.08
SKUN	1	0.08
UNKN	1	0.08

A5. Railroad mortalities through MRPP

Species	Sum of mortality (N)	Percentage (%)
Moose (*Alces alces*)	18	62.07
Deer (*Odocoileus* spp.)	5	17.24
Elk (*Cervus canadensis*)	2	6.90
Black bear (*Ursus americanus*)	2	6.90
Wolf (*Canis lupus*)	2	6.90

14. APPENDIX B: ROAD AND RAILROAD MORTALITIES PER YEAR FOR THE FOCAL SPECIES AND SELECTED OTHER SPECIES IN JNP (ALL ROADS AND THE RAILROAD) AND MRPP (HWY 16 AND THE RAILROAD).

The number of reported road and railroad mortalities per year for the focal species and selected other species in JNP (all roads and the railroad) and MRPP (Hwy 16 and the railroad). All averages are based on a 10 year period from 1 January 2000 through 31 December. Al. = Albreda section, Ro. = Robson section.

JNP all roads	Year										Total	Average
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009		per year
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	1	0	0	0	0	0	1	0	0	1	3	0.3
Canada lynx (*Lynx canadensis*)	0	2	0	0	2	0	1	1	3	2	11	1.1
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	1	0	0	2	0	2	1	1	1	8	0.8
Coyote (*Canis latrans*)	4	1	0	3	9	16	10	10	3	18	74	7.4
Wolf (*Canis lupus*)	1	0	1	3	6	4	4	2	6	2	29	2.9
Black bear (*Ursus americanus*)	5	7	4	2	4	1	2	4	4	2	35	3.5
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	1	0	1	2	0	0	0	0	0	0	4	0.4
Sub total	*12*	*11*	*6*	*10*	*23*	*21*	*20*	*18*	*17*	*26*	*164*	*16.4*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	25	30	26	44	34	36	36	35	42	42	350	35.0
Mule deer (*Odocoileus hemionus)*	25	19	13	13	23	13	20	22	27	15	190	19.0
Deer (*Odocoileus hemionus)*	0	0	0	0	0	0	0	0	0	0	0	0
Elk (*Cervus canadensis*)	32	44	33	33	39	38	38	25	28	28	338	33.8
Moose (*Alces alces)*	3	9	6	10	7	4	4	4	2	4	53	5.3
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	14	14	10	15	11	11	13	15	13	7	123	12.3
Sub total	*99*	*116*	*88*	*115*	*114*	*102*	*111*	*101*	*112*	*96*	*1054*	*105.4*
Total	111	127	94	125	137	123	131	119	129	122	1218	121.8

MRPP Hwy 16	Year											Average
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	per year
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	0	0	0	0	0	0	0	0	0	0	0	0
Canada lynx (*Lynx canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	0	0	0	0	0	0	0	0	0	0	0
Coyote (*Canis latrans*)	0	0	0	1	0	0	0	1	0	0	2	0.2
Wolf (*Canis lupus*)	0	2	0	0	1	2	0	1	0	0	6	0.6
Black bear (*Ursus americanus*)	0	0	1	4	3		2	2	1	1	14	1.4
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*0*	*2*	*1*	*5*	*4*	*2*	*2*	*4*	*1*	*1*	*22*	*2.2*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	0	0	0	0	0	0	0	0	0	0	0	0
Mule deer (*Odocoileus hemionus)*	0	0	0	0	0	0	0	0	0	0	0	0
Deer (*Odocoileus hemionus)*	8	12	0	1	2	7	5	7	8	5	55	5.5
Elk (*Cervus canadensis*)	0	0	1	1	2	0	0	0	0	0	4	0.4
Moose (*Alces alces)*	6	7	12	8	7	3	8	6	3	2	62	6.2
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*14*	*19*	*13*	*10*	*11*	*10*	*13*	*13*	*11*	*7*	*121*	*12.1*
Total	14	21	14	15	15	12	15	17	12	8	143	14.3

Note: For Hwy 16 in MRRP Bear species was never identified; "Bear" was assumed to be black bear

JNP all railroad mortality observations	Year											Average
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	per year
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	0	0	0	0	0	0	0	0	0	0	0	0
Canada lynx (*Lynx canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	0	0	0	0	0	0	1	0	0	1	0.1
Coyote (*Canis latrans*)	0	0	0	0	1	0	1	0	0	1	3	0.3
Wolf (*Canis lupus*)	1	1	0	2	0	0	3	1	1	0	9	0.9
Black bear (*Ursus americanus*)	2	3	4	0	7	2	1	9	2	7	37	3.7
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*3*	*4*	*4*	*2*	*8*	*2*	*5*	*11*	*3*	*8*	*50*	*5.0*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	2	5	1	3	1	2	5	3	6	1	29	2.9
Mule deer (*Odocoileus hemionus)*	1	4	4	7	4	1	3	1	8	5	38	3.8
Deer (*Odocoileus hemionus)*	0	0	0	0	1	0	0	0	0	2	3	0.3
Elk (*Cervus canadensis*)	23	30	19	28	10	11	17	20	5	13	176	17.6
Moose (*Alces alces)*	1	3	3	2	3	5	1	0	0	2	20	2.0
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	11	10	7	8	7	14	12	17	9	6	101	10.1
Sub total	*38*	*52*	*34*	*48*	*26*	*33*	*38*	*41*	*28*	*29*	*367*	*36.7*
Total	41	56	38	50	34	35	43	52	31	37	417	41.7

MRPP railroad, Albreda	Year											Average
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	per year
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	0	0	0	0	0	0	0	0	0	0	0	0
Canada lynx (*Lynx canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	0	0	0	0	0	0	0	0	0	0	0
Coyote (*Canis latrans*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolf (*Canis lupus*)		1									1	0.1
Black bear (*Ursus americanus*)	1								1		2	0.2
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*1*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*3*	*0.3*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	0	0	0	0	0	0	0	0	0	0	0	0
Mule deer (*Odocoileus hemionus)*	0	0	0	0	0	0	0	0	0	0	0	0
Deer (*Odocoileus hemionus)*	1	1						1			3	0.3
Elk (*Cervus canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Moose (*Alces alces)*	4		1			1					6	0.6
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*5*	*1*	*1*	*0*	*0*	*1*	*0*	*1*	*0*	*0*	9	*0.9*
Total	6	2	1	0	0	1	0	1	1	0	12	1.2

MRPP railroad, Robson	Year										Total	Average per year
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009		
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	0	0	0	0	0	0	0	0	0	0	0	0
Canada lynx (*Lynx canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	0	0	0	0	0	0	0	0	0	0	0
Coyote (*Canis latrans*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolf (*Canis lupus*)	0	0	0	0	0	0	0	0	0	1	1	0.1
Black bear (*Ursus americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*	*0.1*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	0	0	0	0	0	0	0	0	0	0	0	0
Mule deer (*Odocoileus hemionus)*	0	0	0	0	0	0	0	0	0	0	0	0
Deer (*Odocoileus hemionus)*	0	0	0	0	0	0	0	0	0	0	0	0
Elk (*Cervus canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Moose (*Alces alces)*	0	0	0	0	0	0	0	0	0	0	0	0
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Total	0	0	0	0	0	0	0	0	0	1	1	0.1

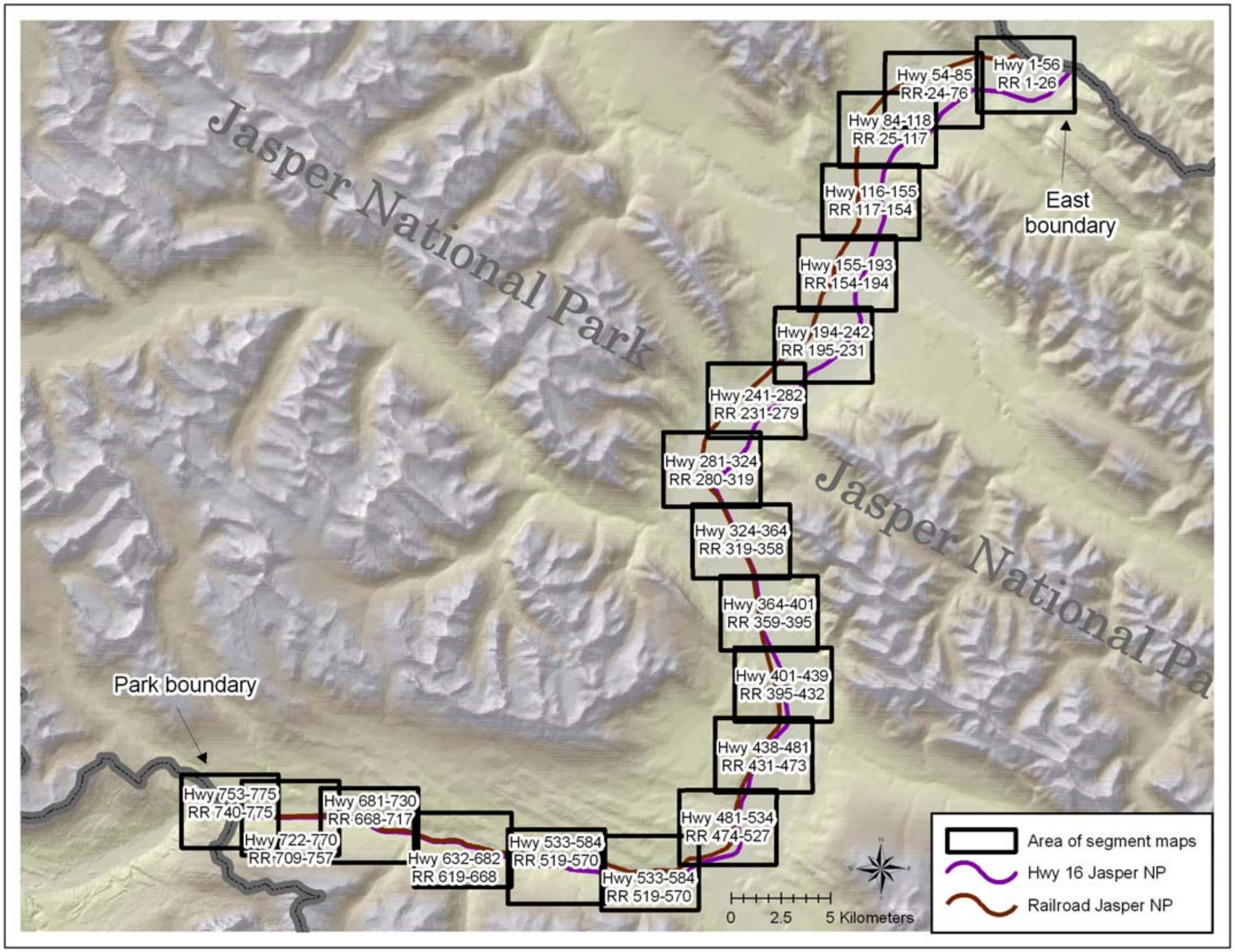
15. APPENDIX C: ROAD AND RAILROAD MORTALITIES PER YEAR FOR THE FOCAL SPECIES AND SELECTED OTHER SPECIES IN JNP (WITHIN 500 M FROM HWY 16 OR RAILROAD).

The number of reported road and railroad mortalities per year for the focal species and selected other species in JNP (within 500 m from Hwy 16 or the railroad). All averages are based on a 10 year period from 1 January 2000 through 31 December.

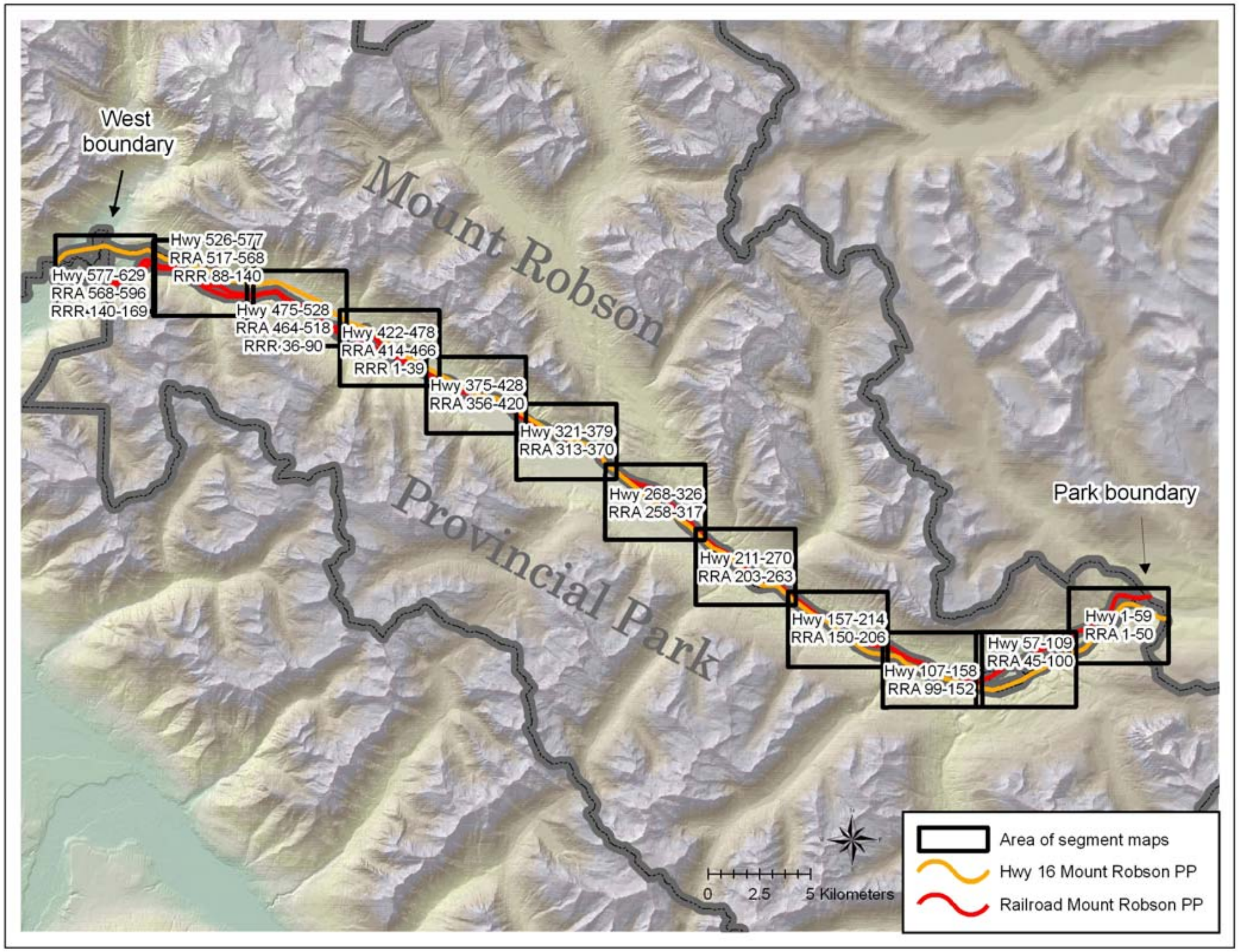
JNP Hwy 16, within 500 m	Year											Average
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total	per year
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	1	0	0	0	0	0	1	0	0	0	2	0.2
Canada lynx (*Lynx canadensis*)	0	2	0	0	0	0	1	1	2	2	8	0.8
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	0	0	0	2	0	2	0	0	1	5	0.5
Coyote (*Canis latrans*)	2	1	0	2	9	8	9	9	3	16	59	5.9
Wolf (*Canis lupus*)	1	0	1	3	5	4	2	2	4	2	24	2.4
Black bear (*Ursus americanus*)	3	6	3	1	2	1	2	3	2	1	24	2.4
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*7*	*9*	*4*	*6*	*18*	*13*	*17*	*15*	*11*	*22*	*122*	*12.2*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	20	26	19	34	27	20	26	26	27	35	260	26.0
Mule deer (*Odocoileus hemionus)*	13	14	8	11	19	10	15	14	22	9	135	13.5
Deer (*Odocoileus* spp.)	0	0	0	0	1	1	1	1	2	2	8	0.8
Elk (*Cervus canadensis*)	28	36	26	30	31	34	28	20	20	23	276	27.6
Moose (*Alces alces)*	3	6	6	8	5	3	4	3	2	4	44	4.4
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	13	12	9	15	10	9	12	15	12	6	113	11.3
Sub total	*77*	*94*	*68*	*98*	*93*	*77*	*86*	*79*	*85*	*79*	*836*	*83.6*
Total	84	103	72	104	111	90	103	94	96	101	958	95.8

JNP railroad, within 500 m	Year										Total	Average
Species	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009		per year
Focal species												
Fisher (*Martes pennanti*)	0	0	0	0	0	0	0	0	0	0	0	0
Wolverine (*Gulo gulo*)	0	0	0	0	0	0	0	0	0	0	0	0
Canada lynx (*Lynx canadensis*)	0	0	0	0	0	0	0	0	0	0	0	0
Cougar (*Puma concolor*)	0	0	0	0	0	0	0	0	0	0	0	0
Red fox (*Vulpes vulpes*)	0	0	0	0	0	0	0	1	0	0	1	0.1
Coyote (*Canis latrans*)	0	0	0	0	1	0	1	0	0	1	3	0.3
Wolf (*Canis lupus*)	1	1	0	2	0	0	3	1	1	0	9	0.9
Black bear (*Ursus americanus*)	1	1	4	0	6	2	1	9	2	7	33	3.3
Grizzly bear (*Ursus arctos*)	0	0	0	0	0	0	0	0	0	0	0	0
Woodland caribou (*Rangifer tarandus caribou*)	0	0	0	0	0	0	0	0	0	0	0	0
Sub total	*2*	*2*	*4*	*2*	*7*	*2*	*5*	*11*	*3*	*8*	*46*	*4.6*
Selected other species												
White-tailed deer (*Odocoileus virginianus)*	2	5	1	2	1	2	5	3	6	0	27	2.7
Mule deer (*Odocoileus hemionus)*	1	4	4	7	2	1	3	1	8	5	36	3.6
Deer (*Odocoileus hemionus)*	0	0	0	0	1	0	0	0	0	2	3	0.3
Elk (*Cervus canadensis*)	23	27	19	26	6	9	13	20	5	11	159	15.9
Moose (*Alces alces)*	1	3	3	2	3	5	1	0	0	1	19	1.9
Mountain goat (*Oreamnos americanus*)	0	0	0	0	0	0	0	0	0	0	0	0
Bighorn sheep (*Ovis canadensis*)	11	9	6	8	7	14	12	17	9	6	99	9.9
Sub total	*38*	*48*	*33*	*45*	*20*	*31*	*34*	*41*	*28*	*25*	*343*	*34.3*
Total	40	50	37	47	27	33	39	52	31	33	389	38.9

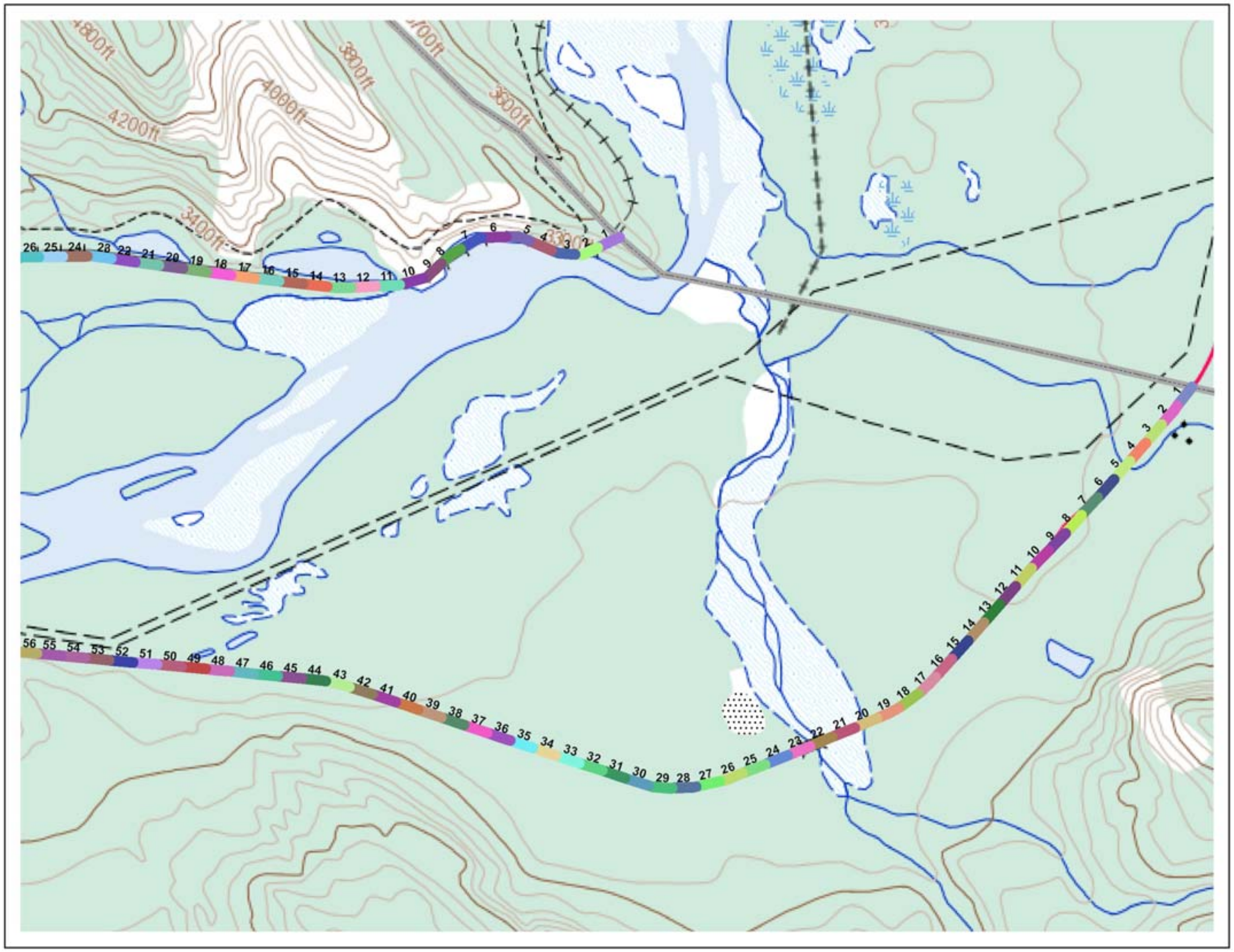
16. APPENDIX D: TOPOGRAPHIC MAPS WITH 100 M UNITES FOR HWY 16 AND THE RAILROAD THROUGH JNP AND MRPP.



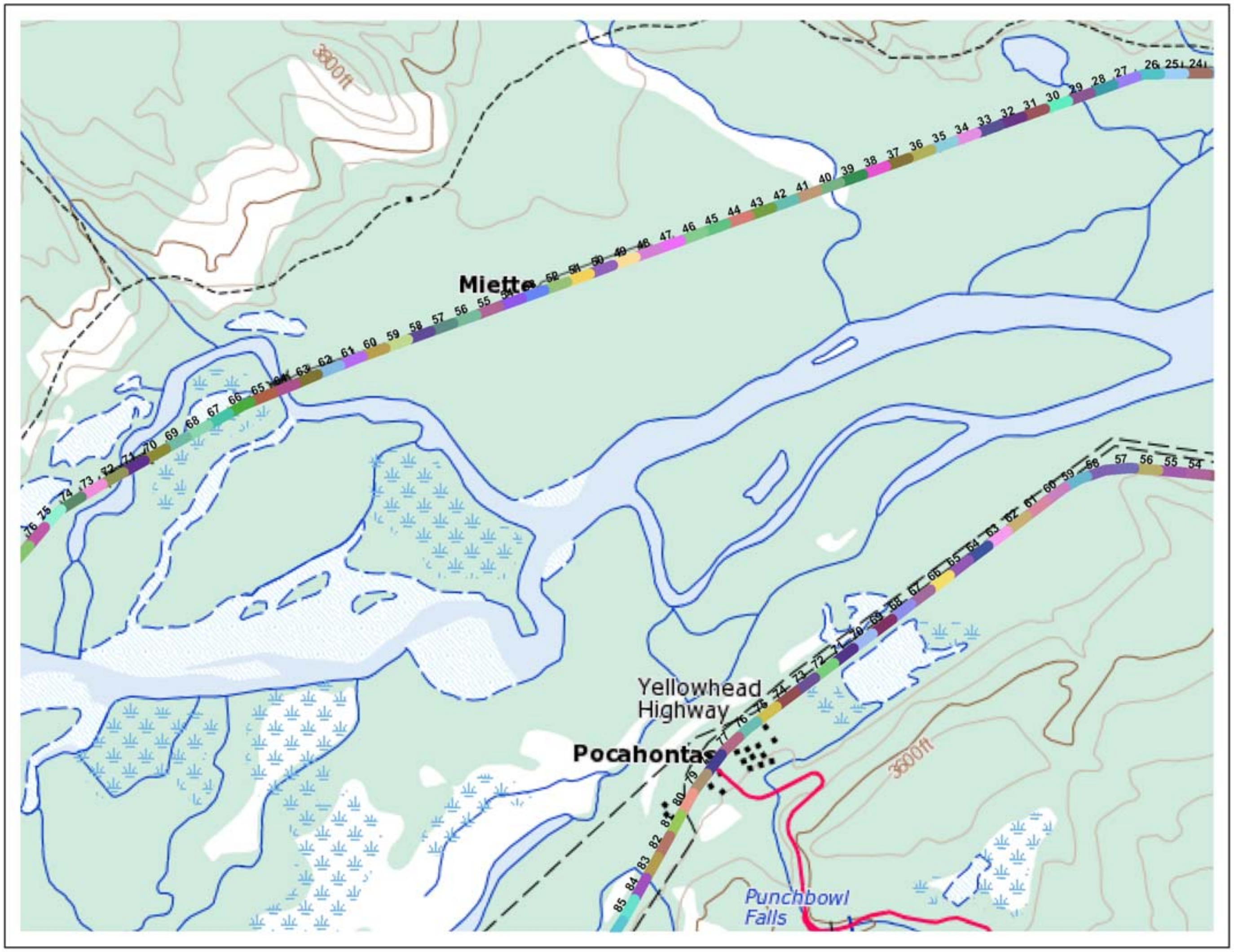
OVERVIEW SEGMENT MAPS JNP



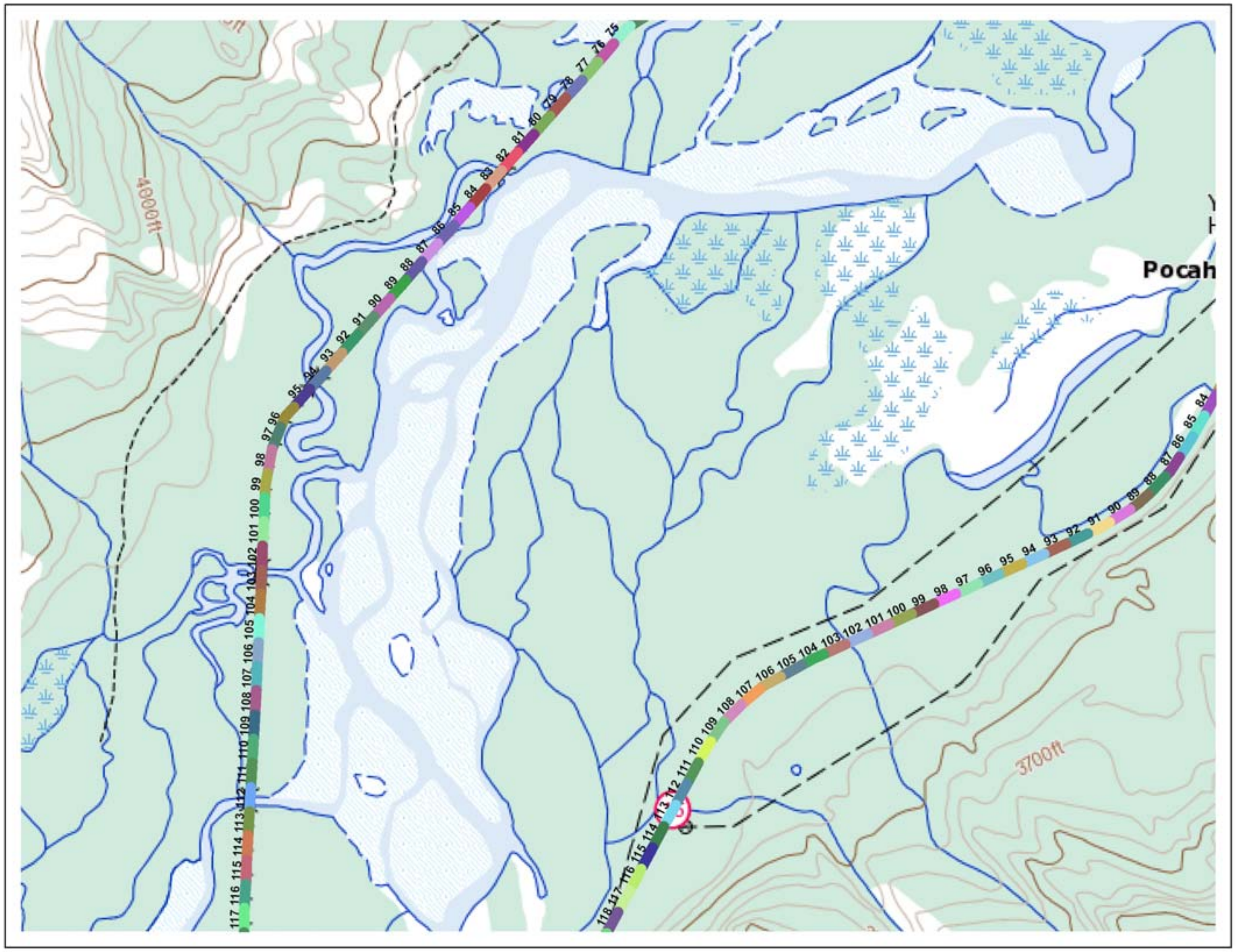
OVERVIEW SEGMENT MAPS MRPP



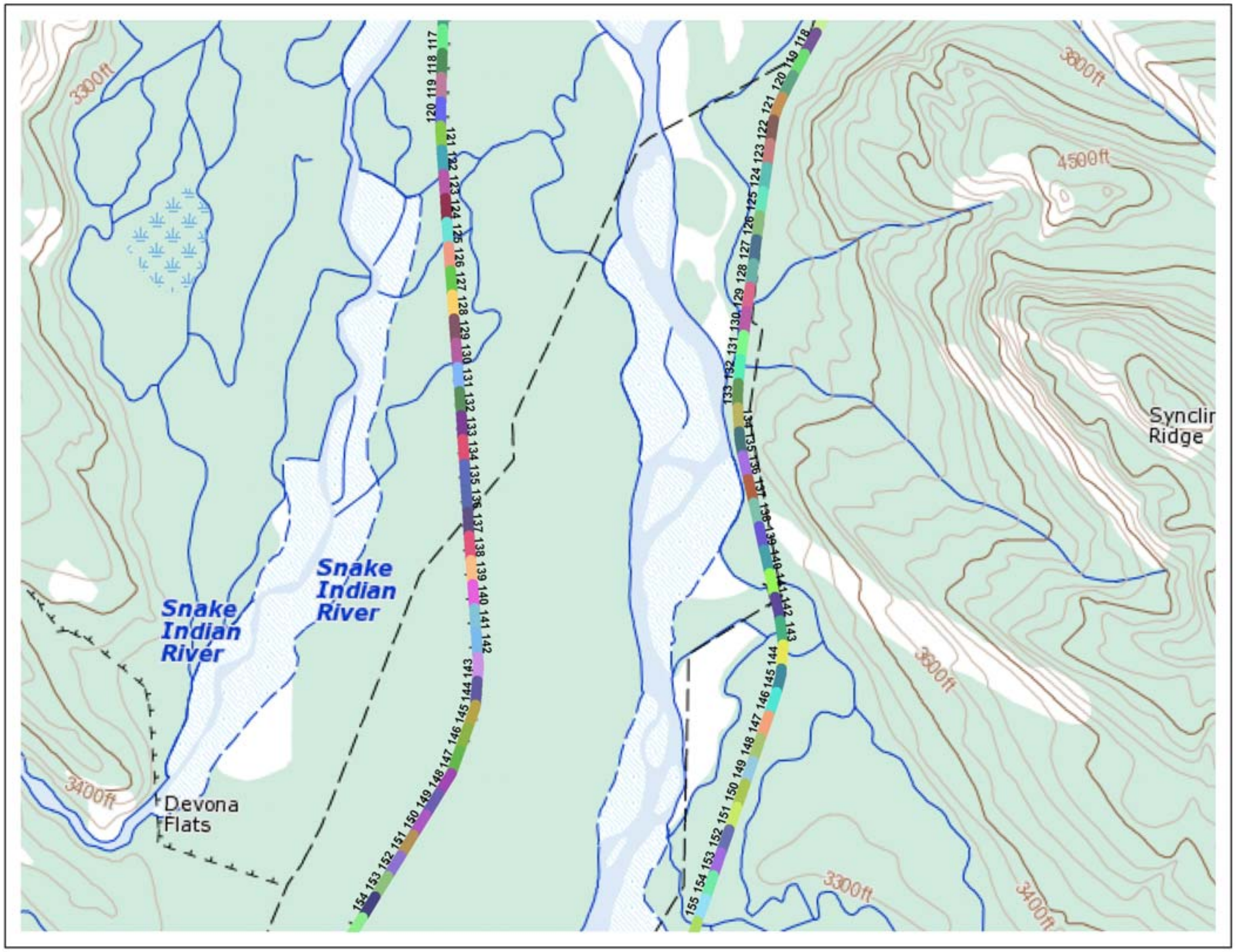
JNP HWY 16 1-56; RAILROAD 1-26



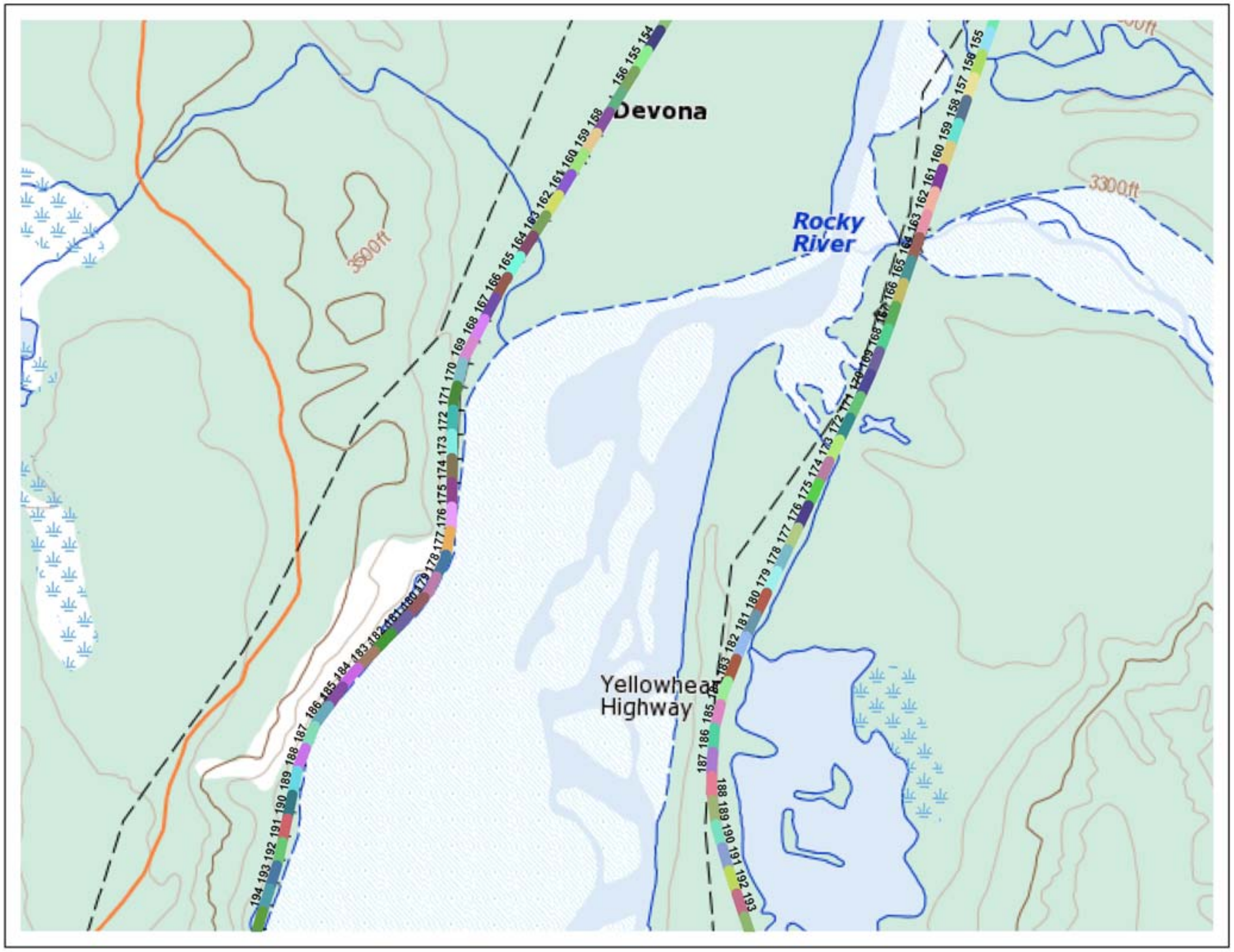
JNP HWY 16 54-85; RAILROAD 24-76



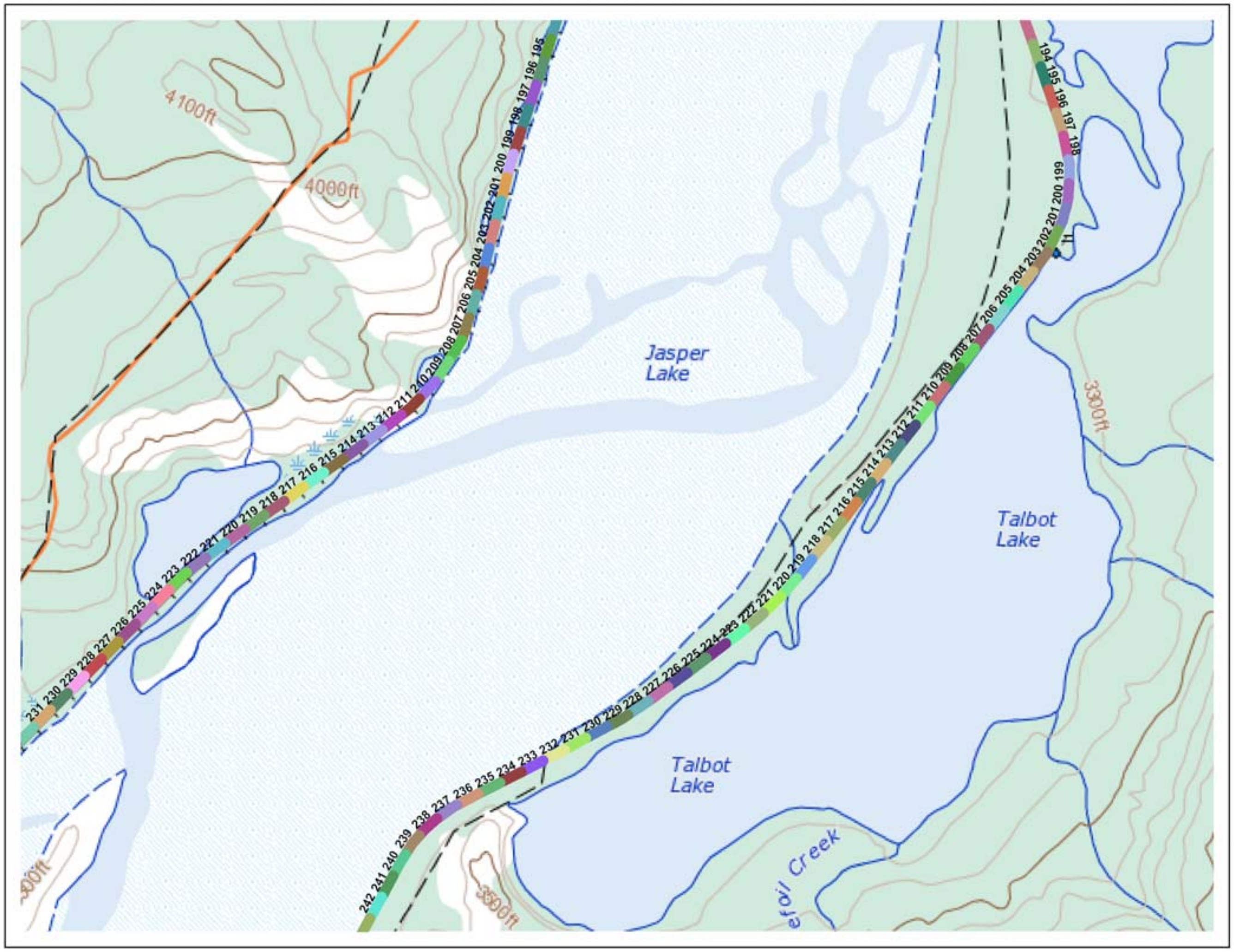
JNP HWY 16 84-118; RAILROAD 75-117



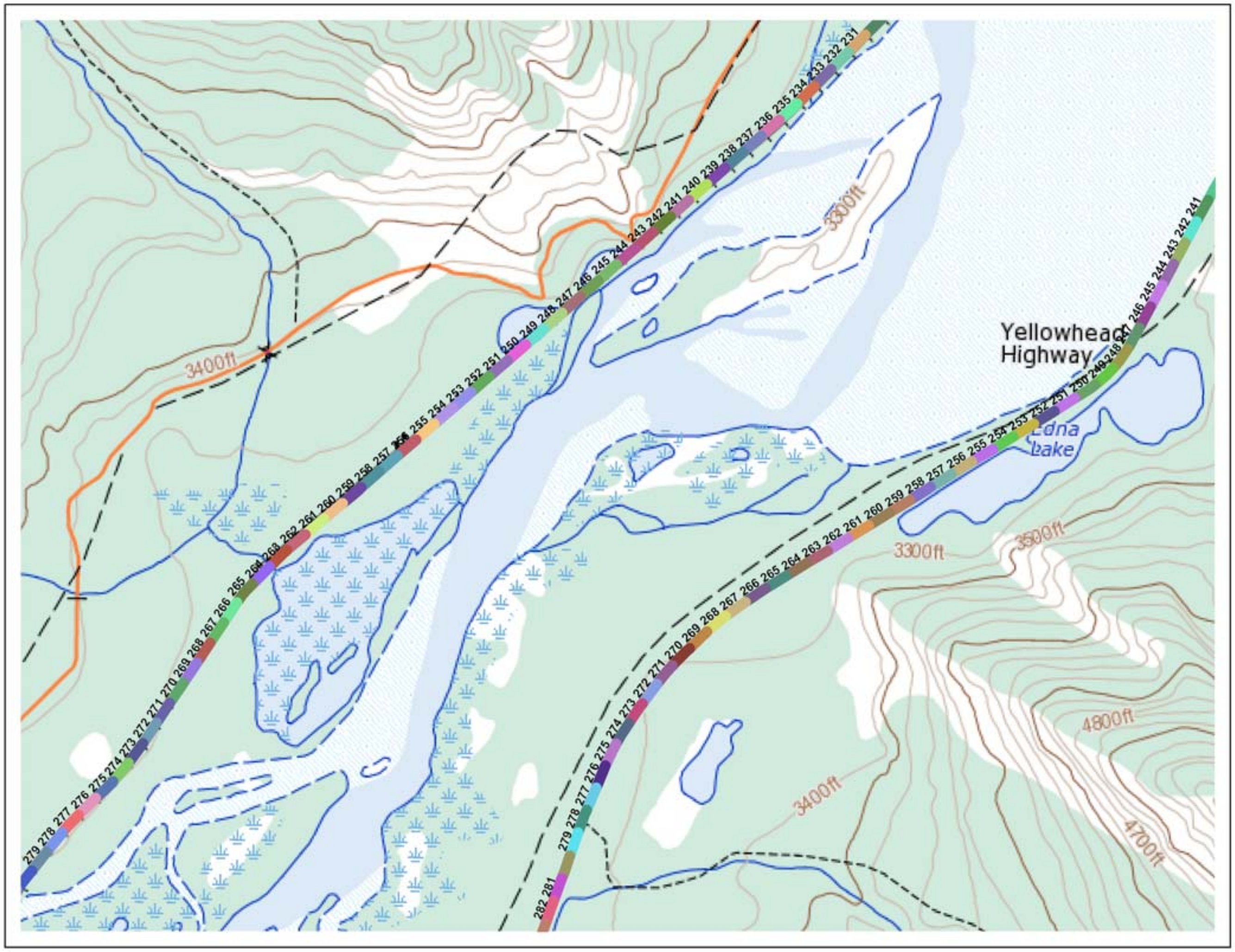
JNP HWY 16 118-155; RAILROAD 117-154



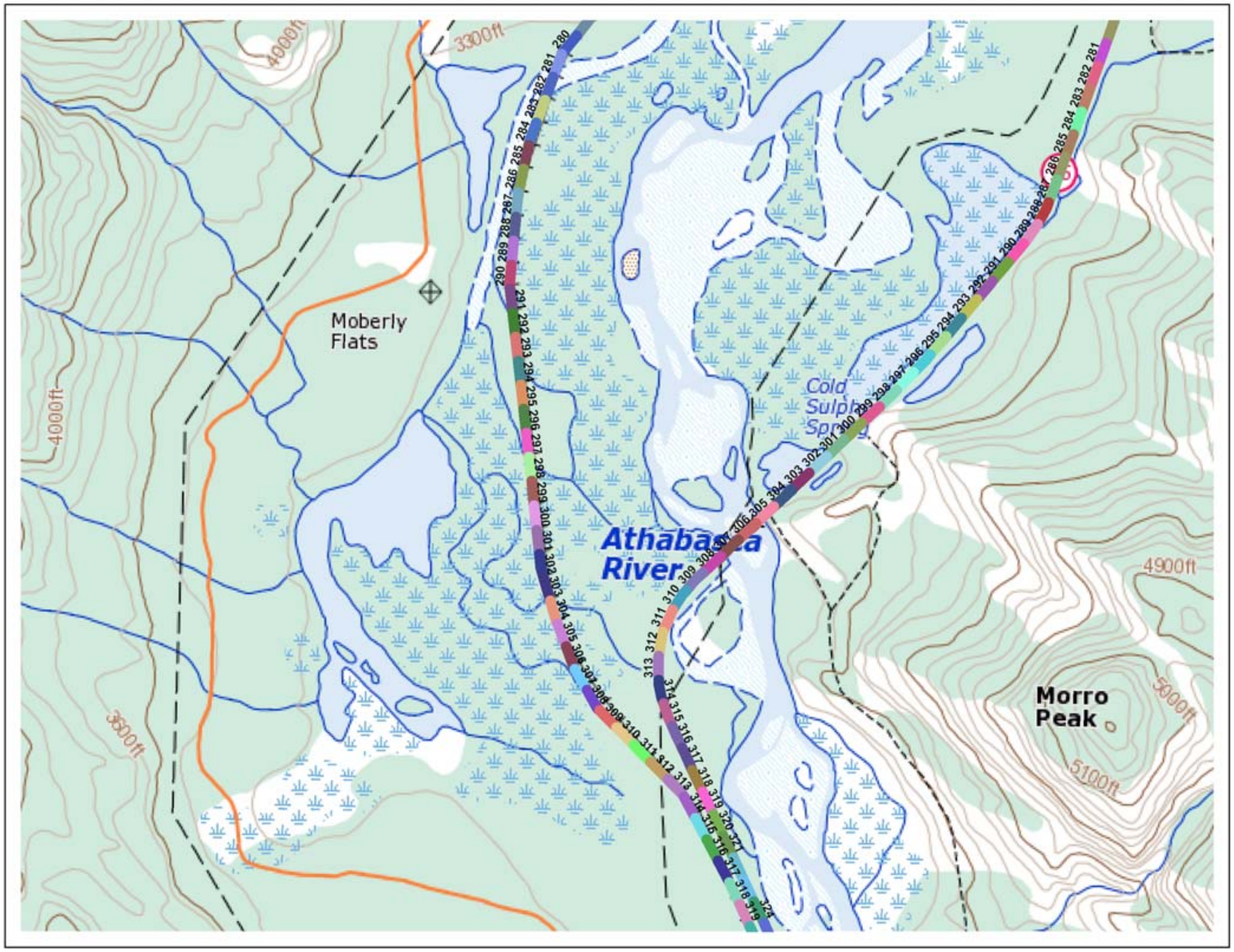
JNP HWY 16 155-193; RAILROAD 154-194



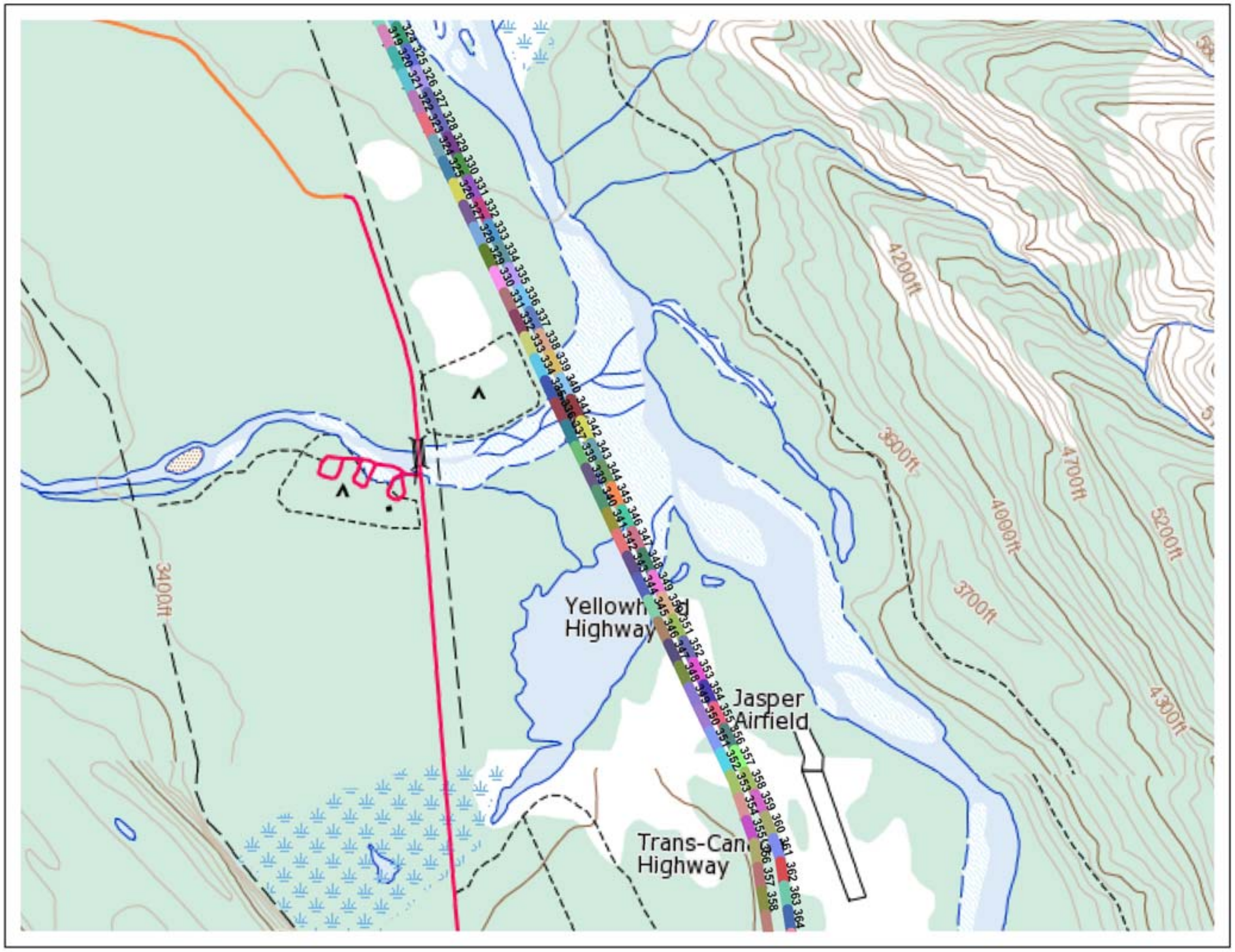
JNP HWY 16 194-242; RAILROAD 195-231



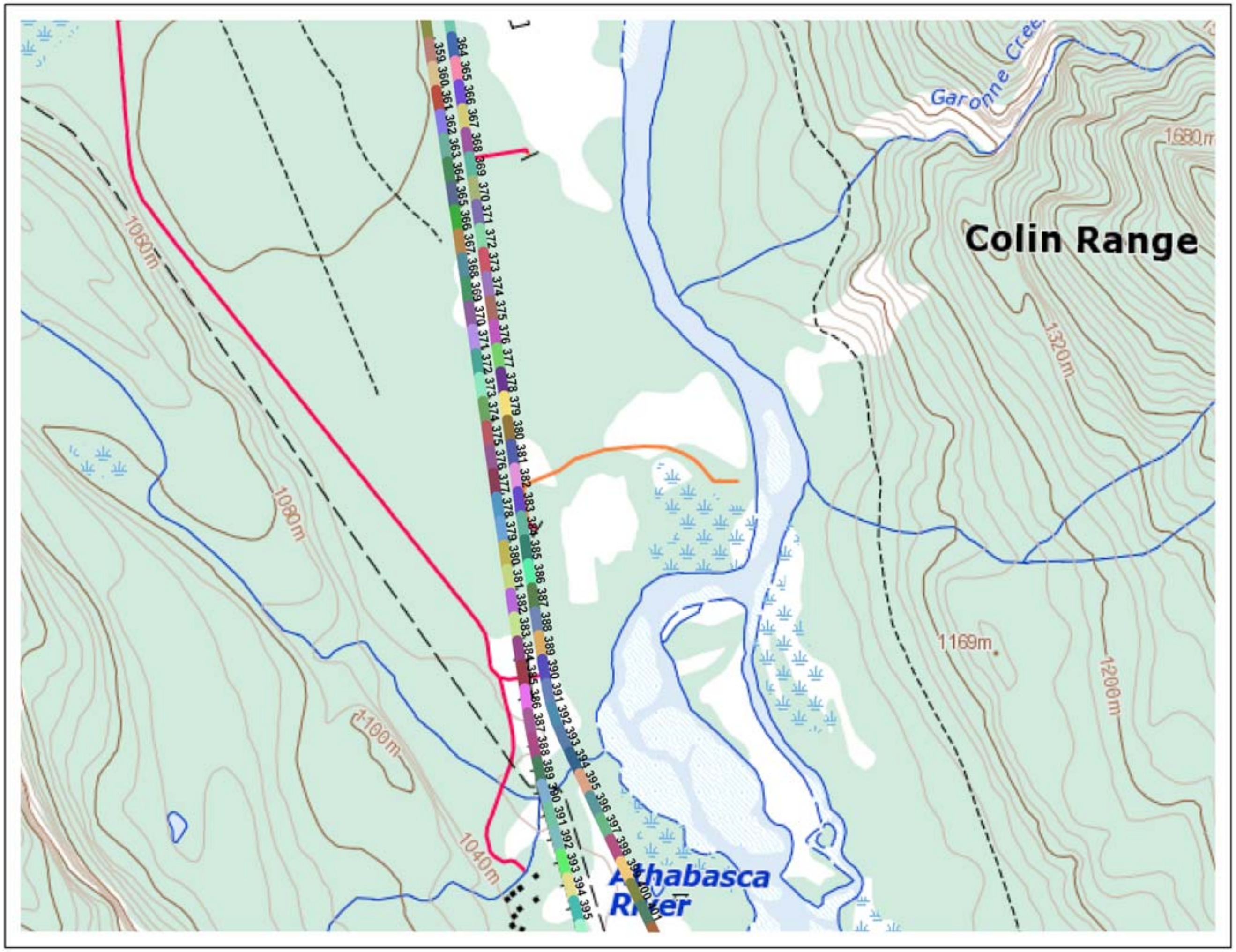
JNP HWY 16 241-282; RAILROAD 231-279



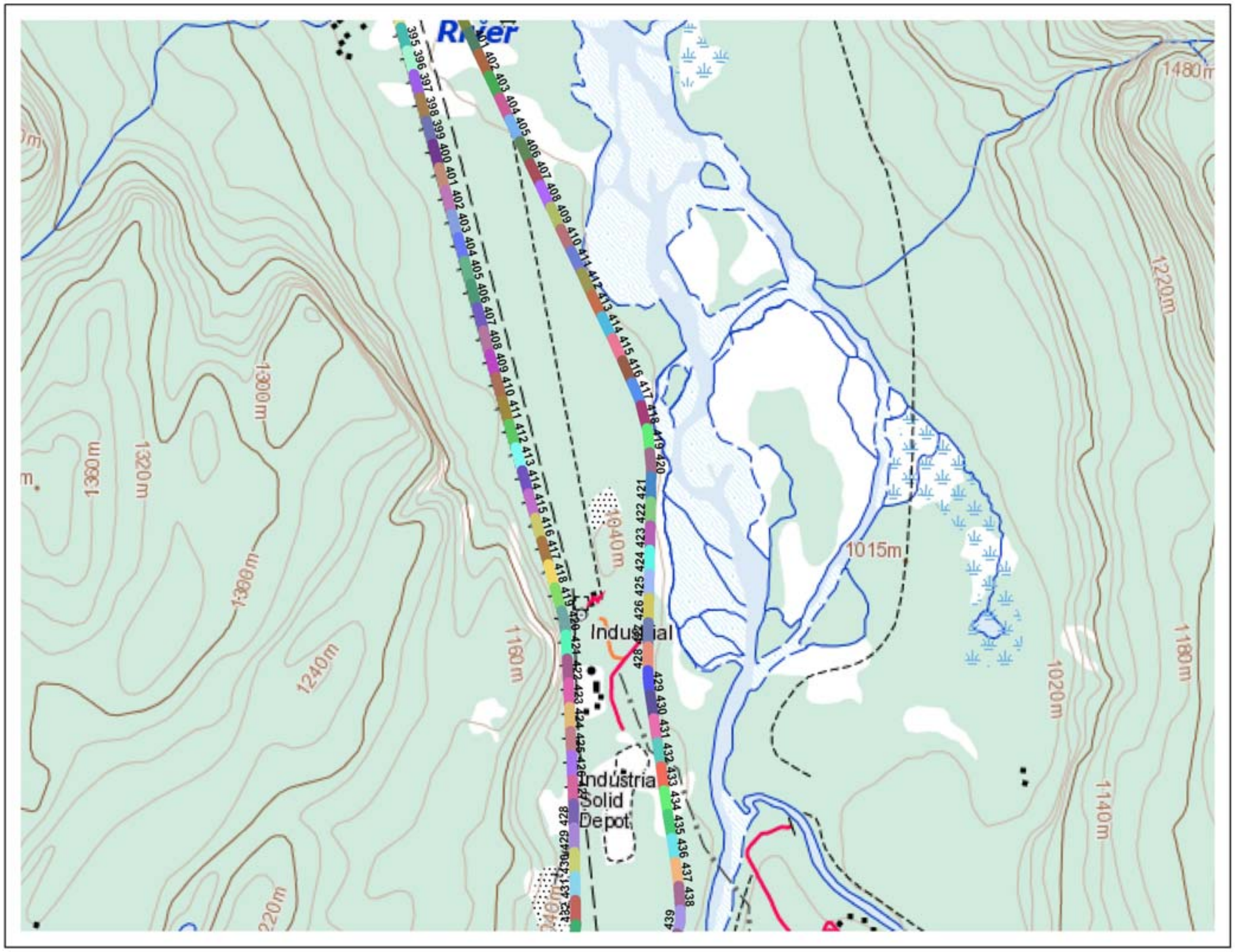
JNP HWY 16 281-324; RAILROAD 280-319



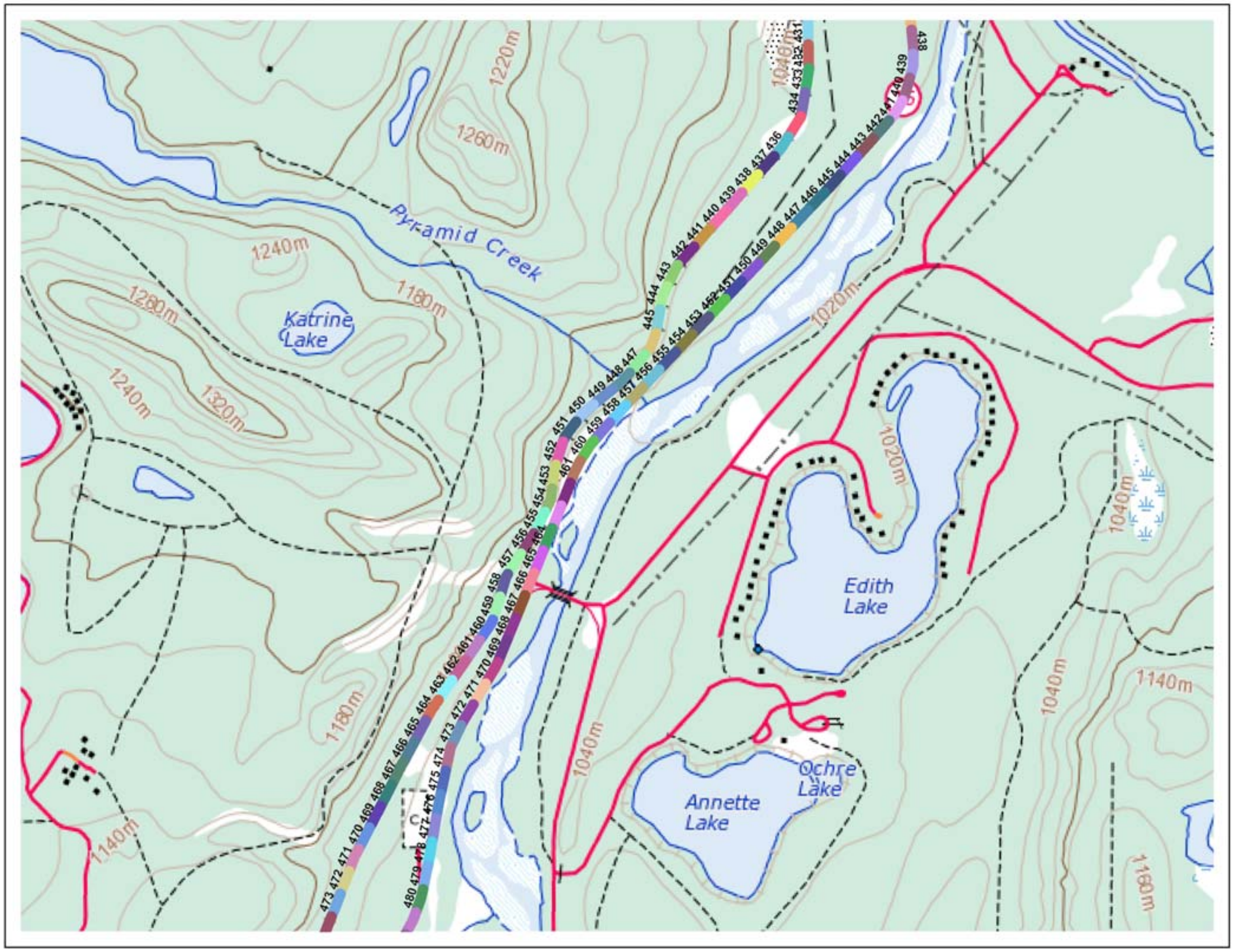
JNP HWY 16 324-364; RAILROAD 319-358



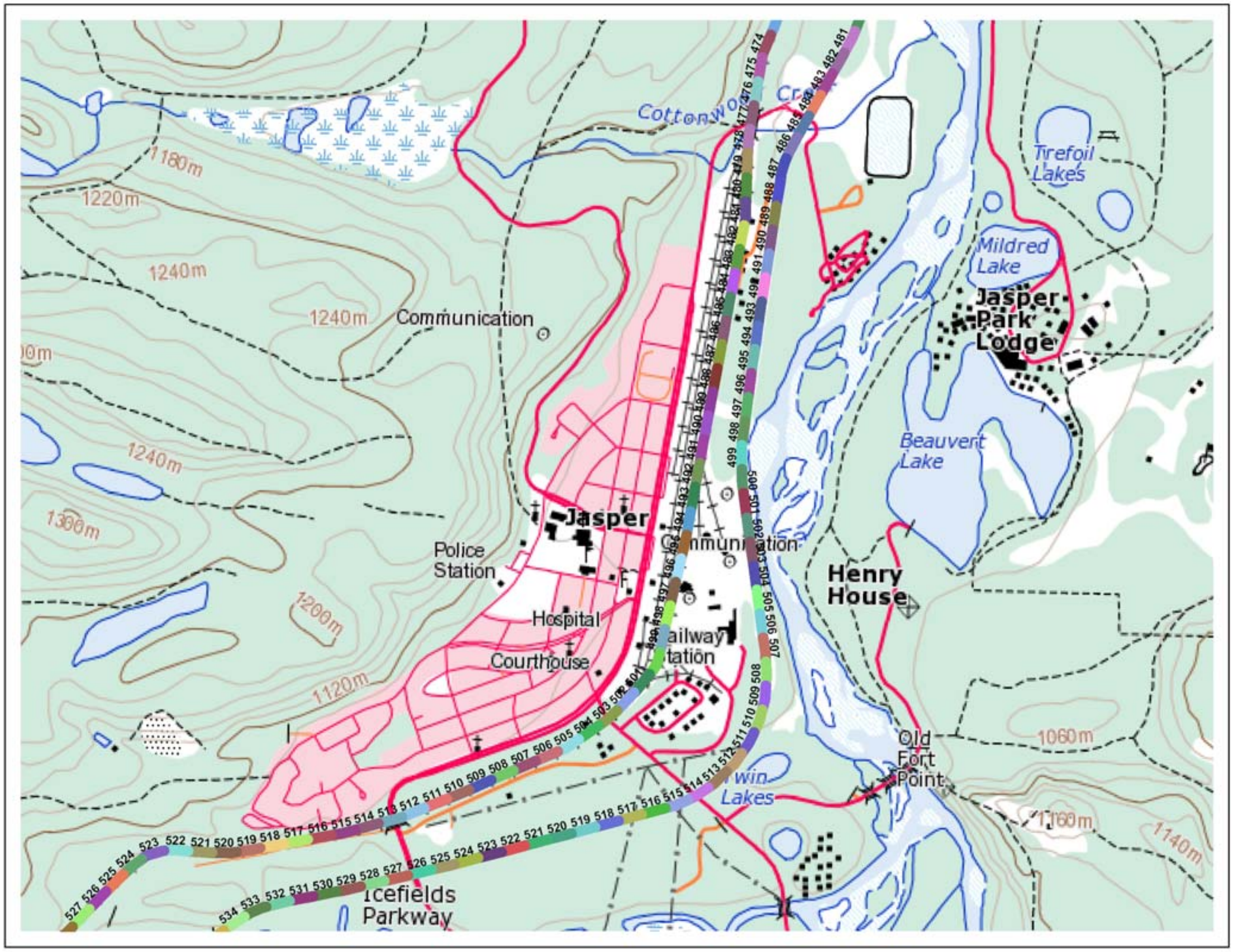
JNP HWY 16 364-401; RAILROAD 359-395



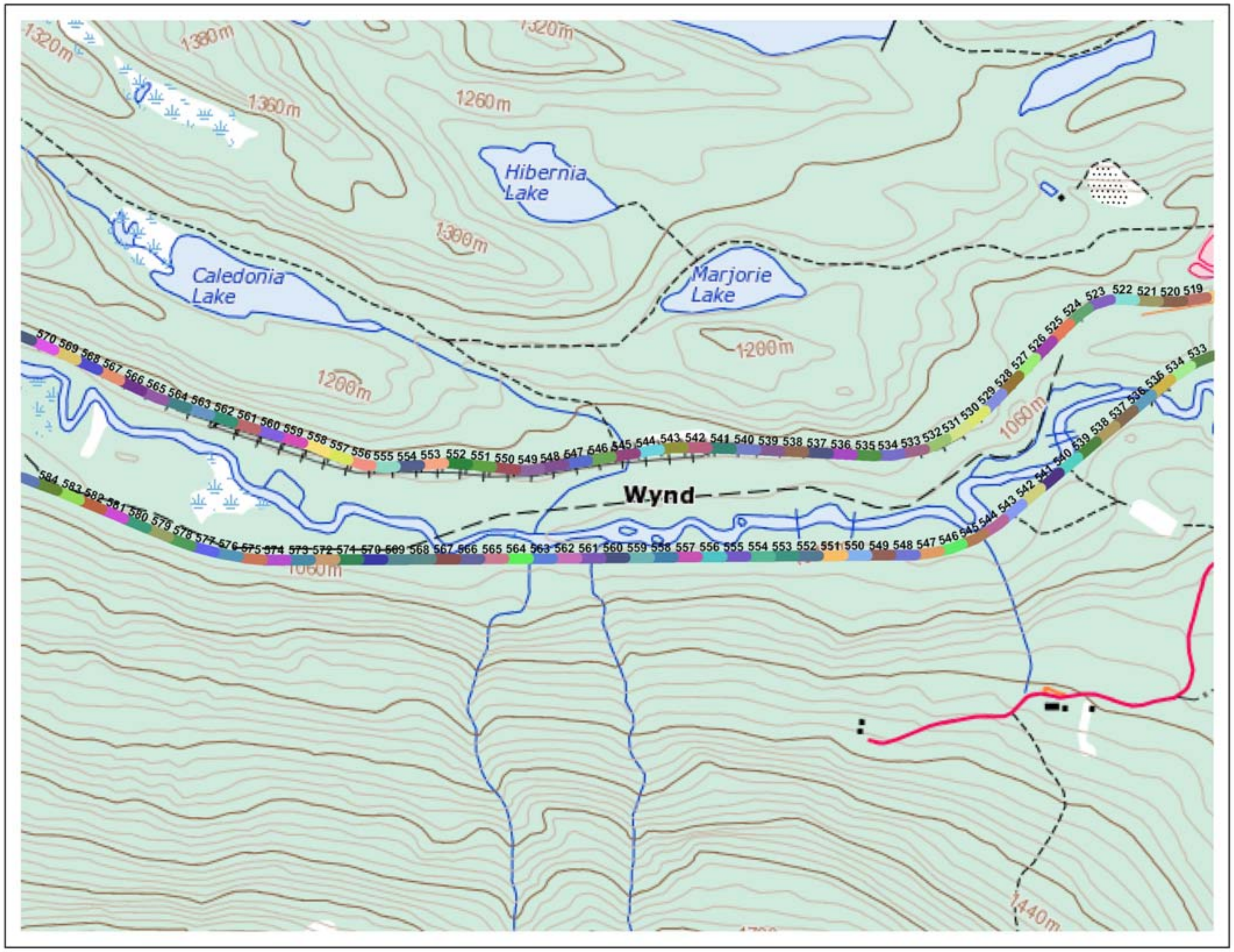
JNP HWY 16 401-439; RAILROAD 395-432



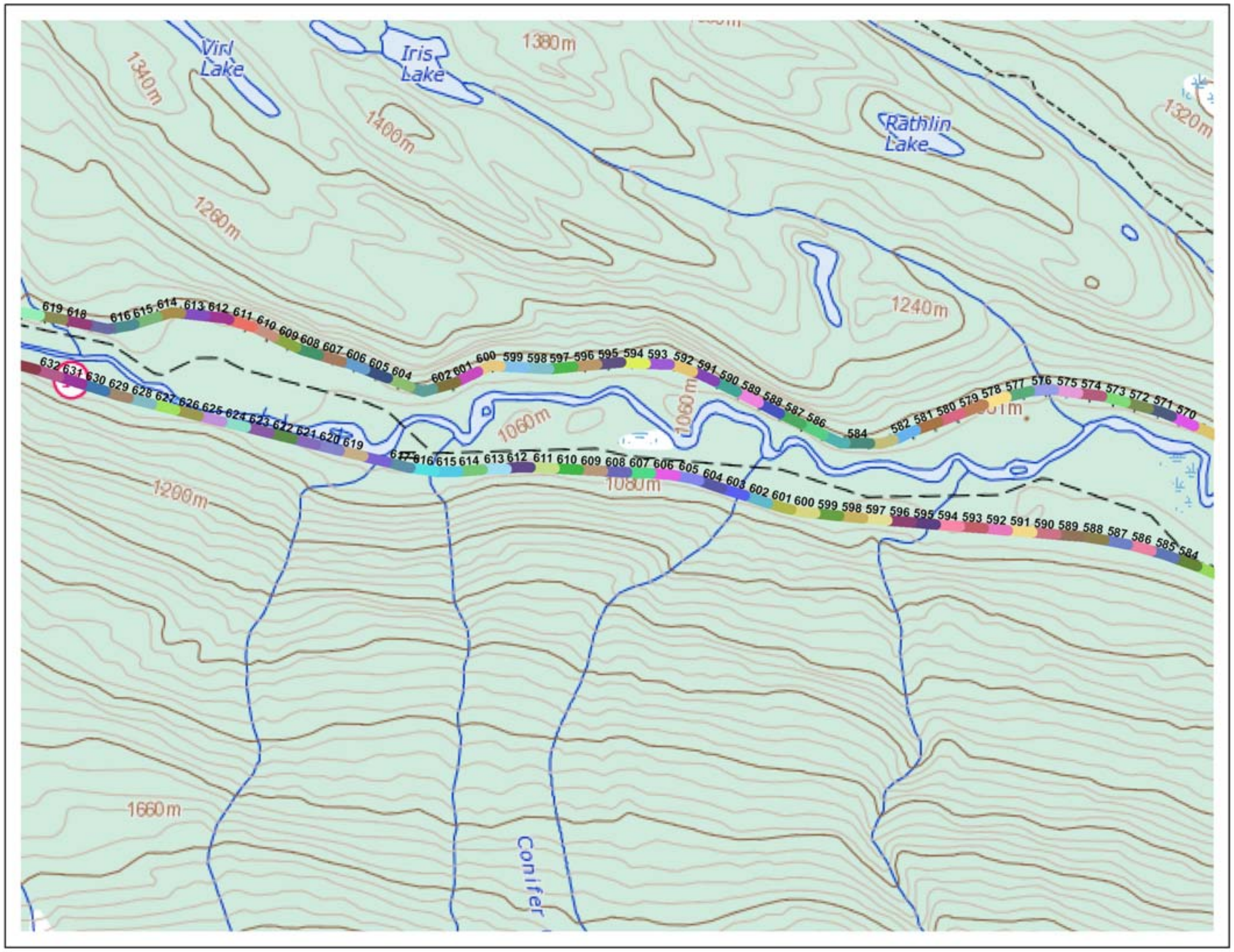
JNP HWY 16 438-480; RAILROAD 431-473



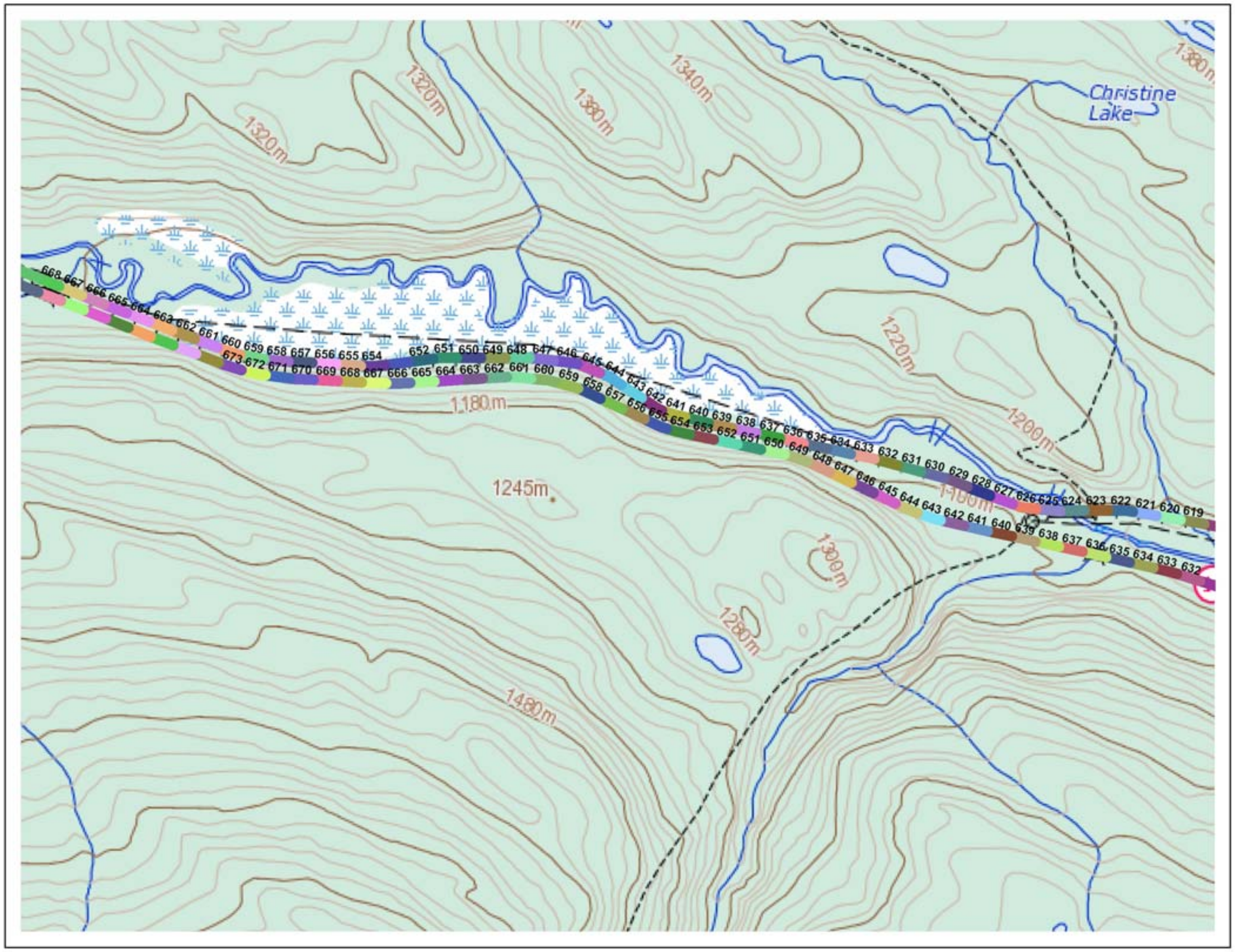
JNP HWY 16 481-534; RAILROAD 474-527



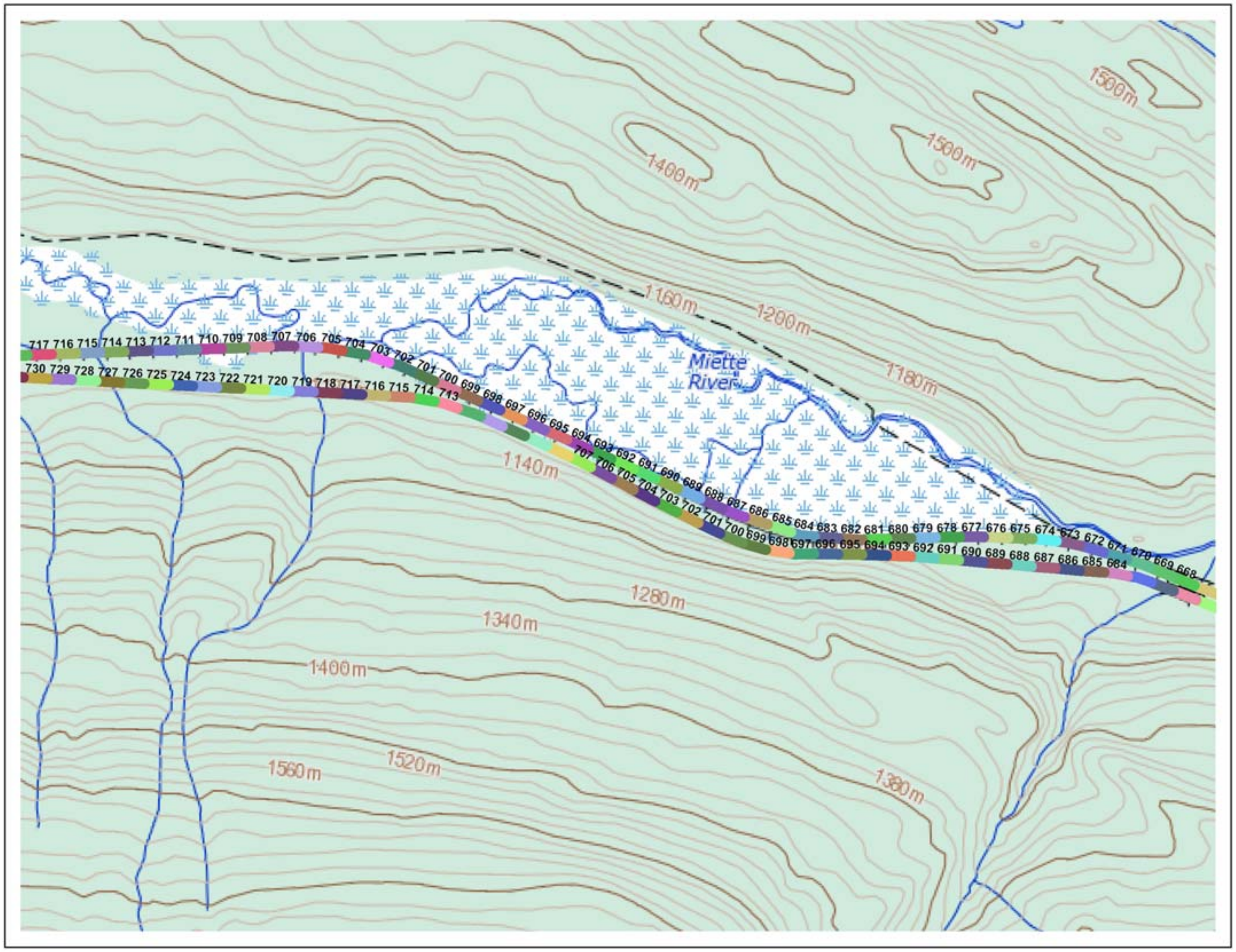
JNP HWY 16 533-584; RAILROAD 519-570



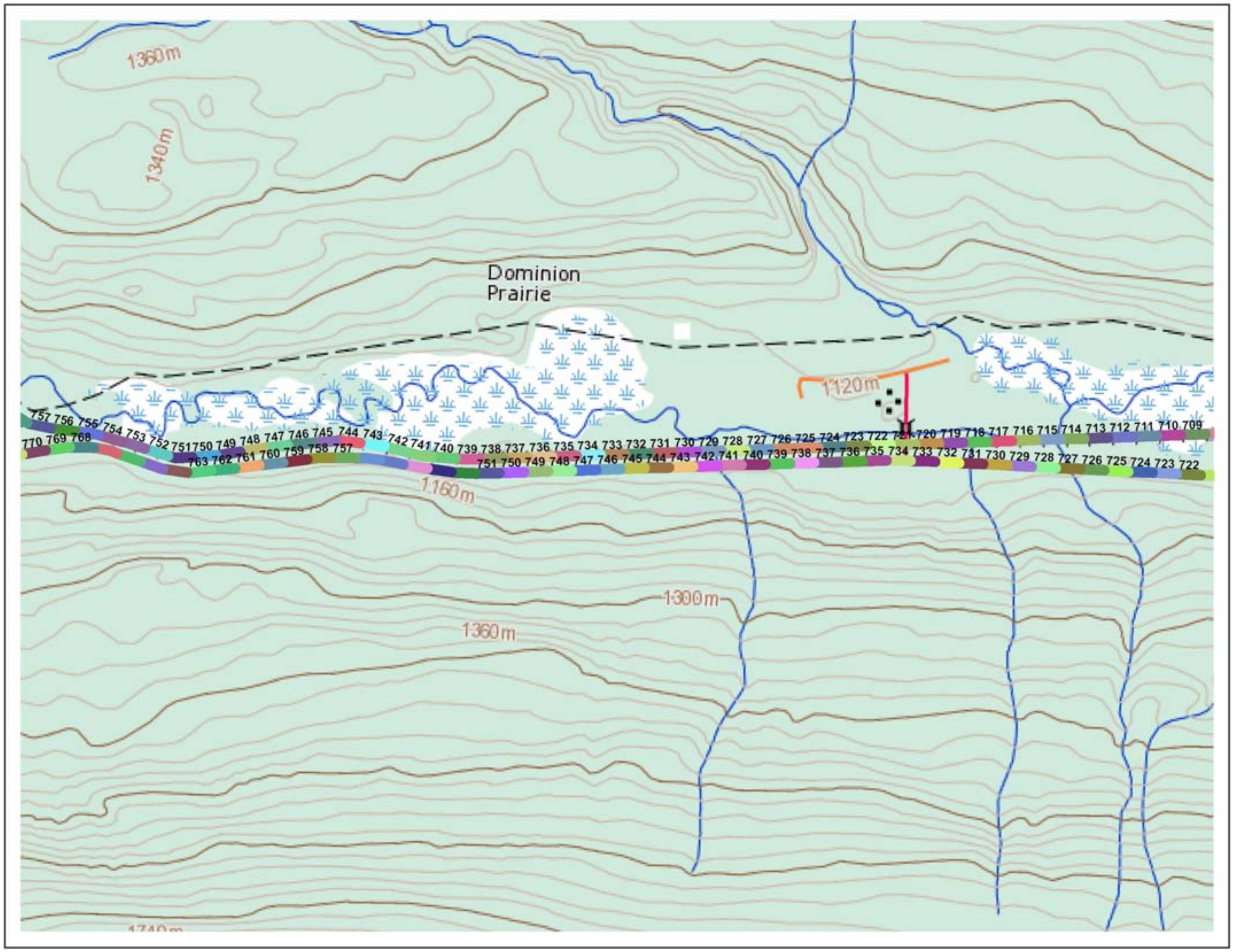
JNP HWY 16 584-632; RAILROAD 570-619



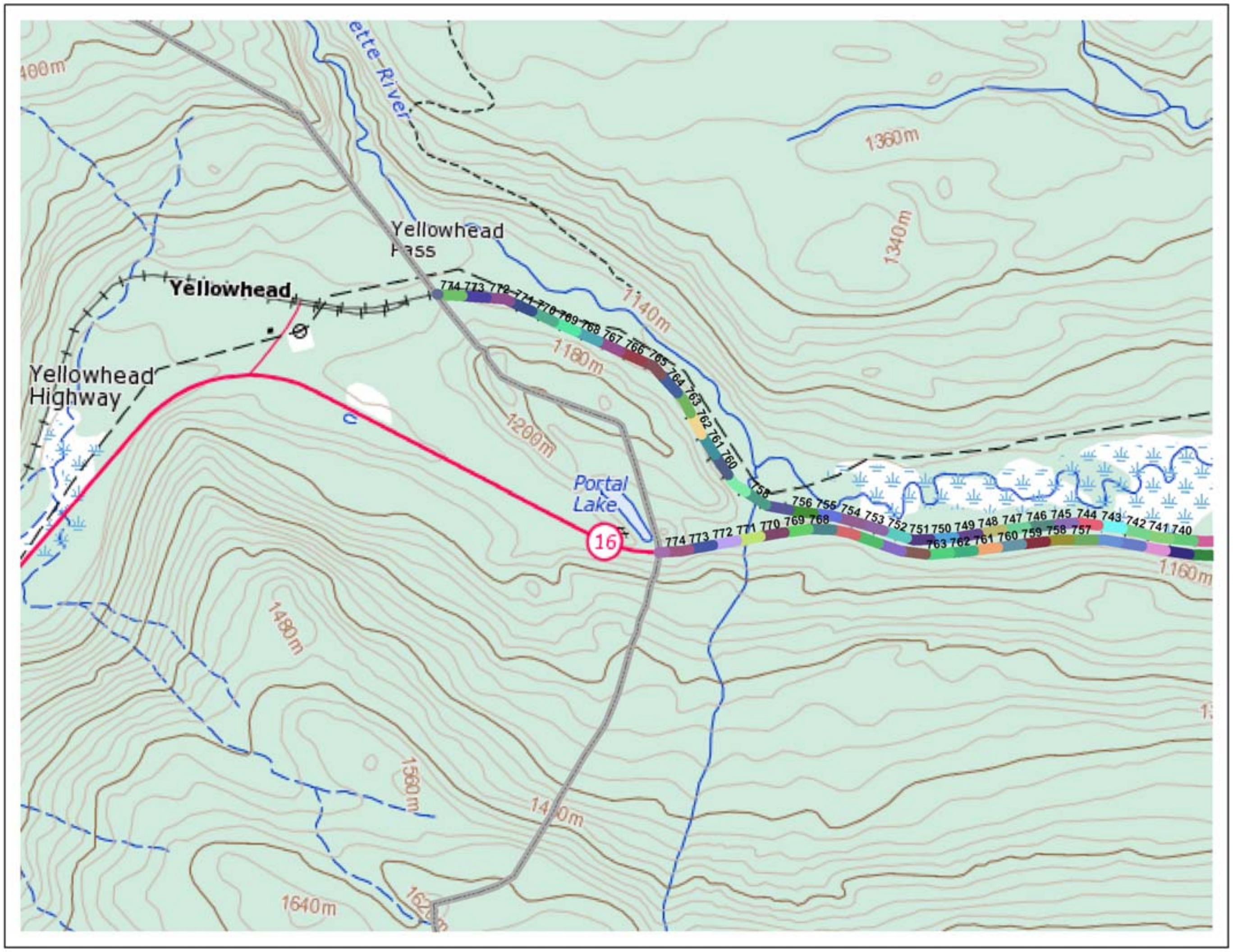
JNP HWY 16 632-681; RAILROAD 619-668



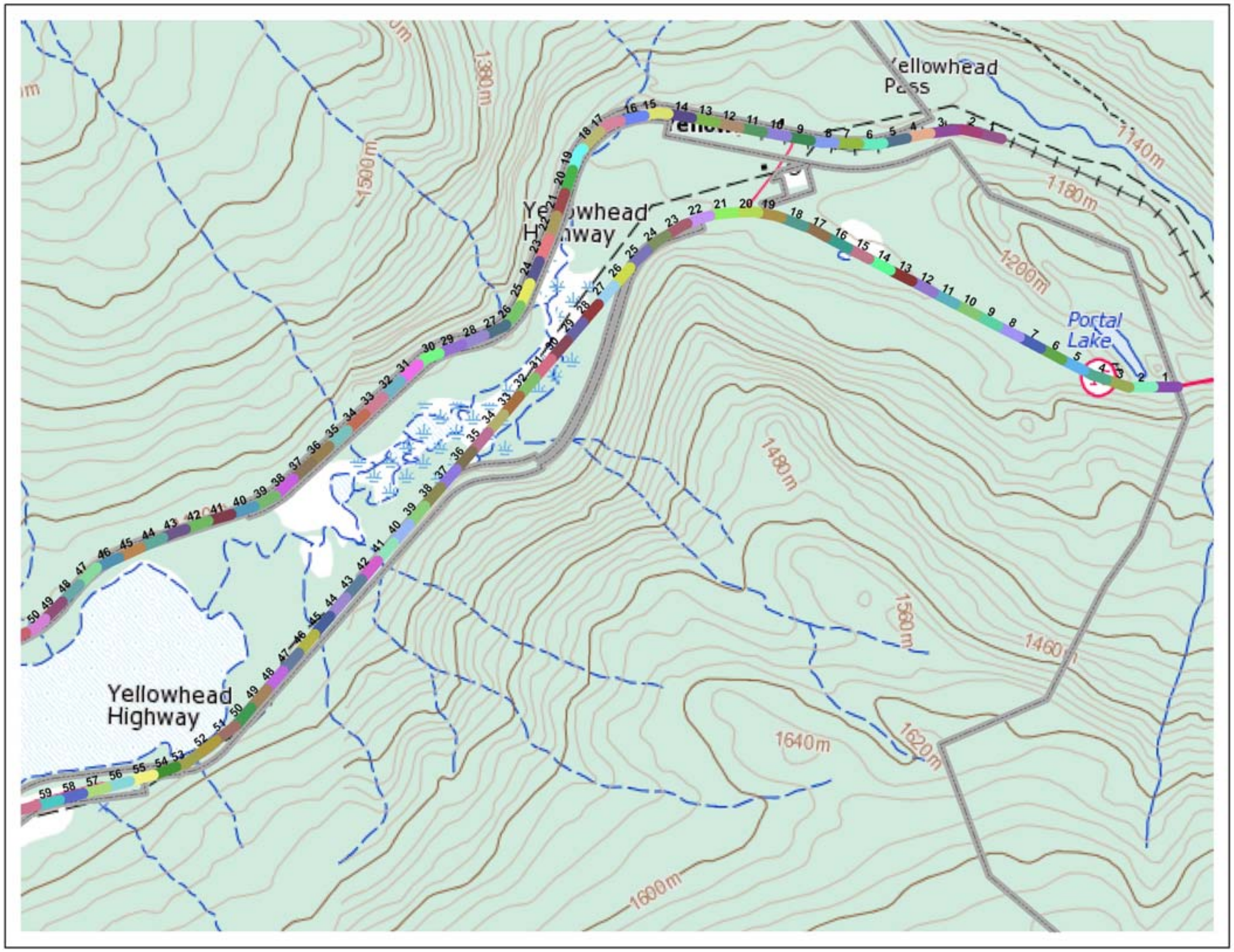
JNP HWY 16 681-730; RAILROAD 668-717



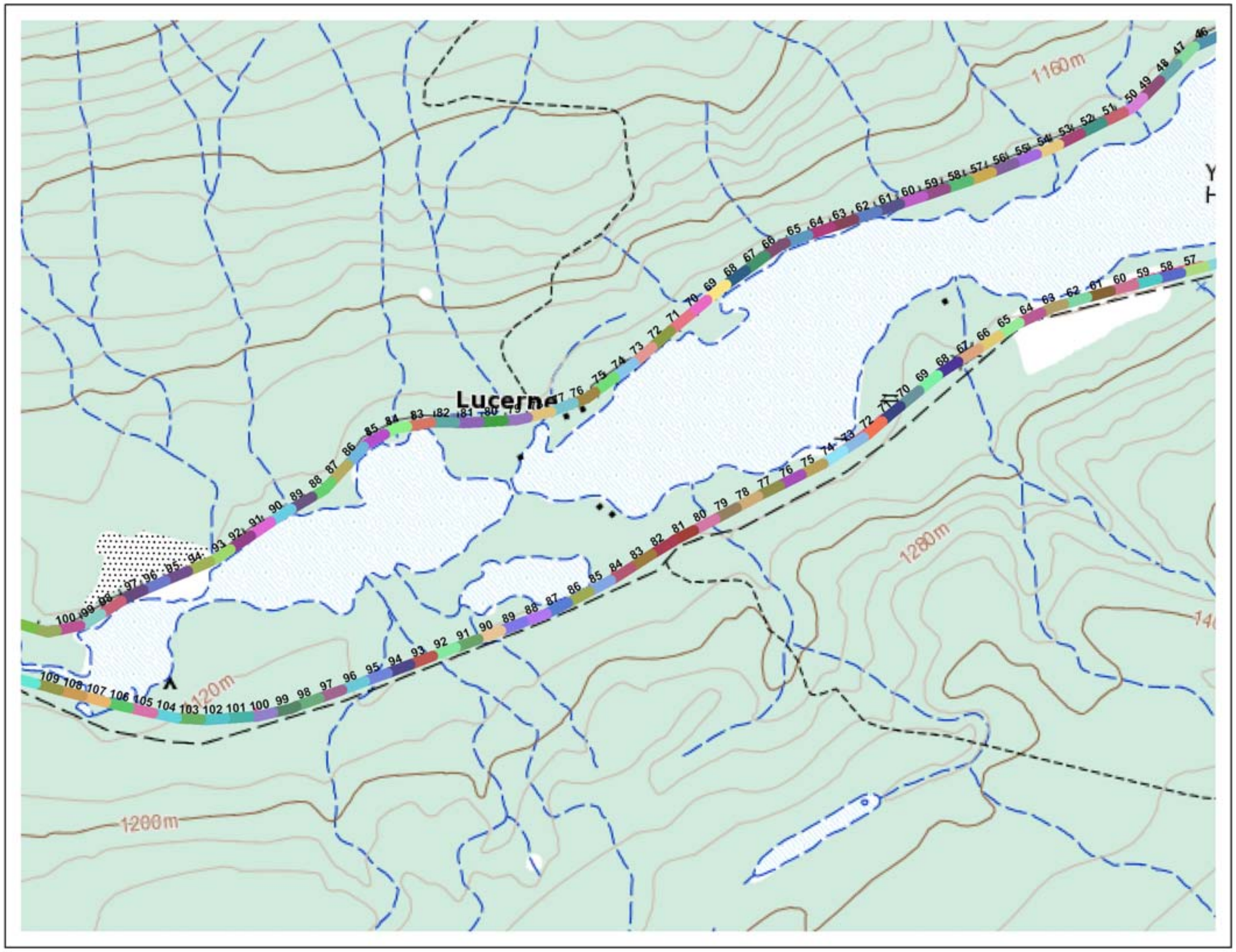
JNP HWY 16 722-770; RAILROAD 709-757



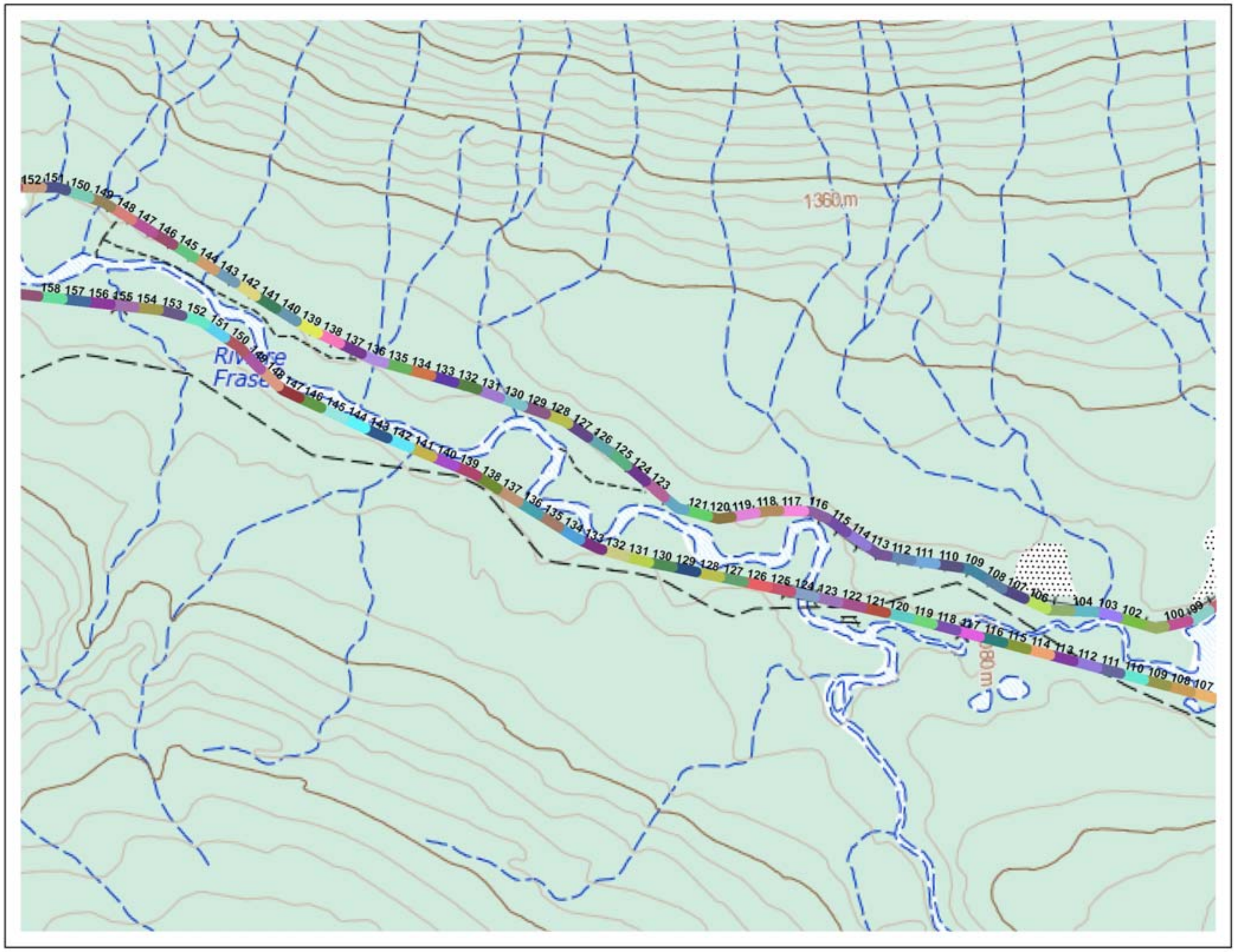
JNP HWY 16 753-774; RAILROAD 740-774



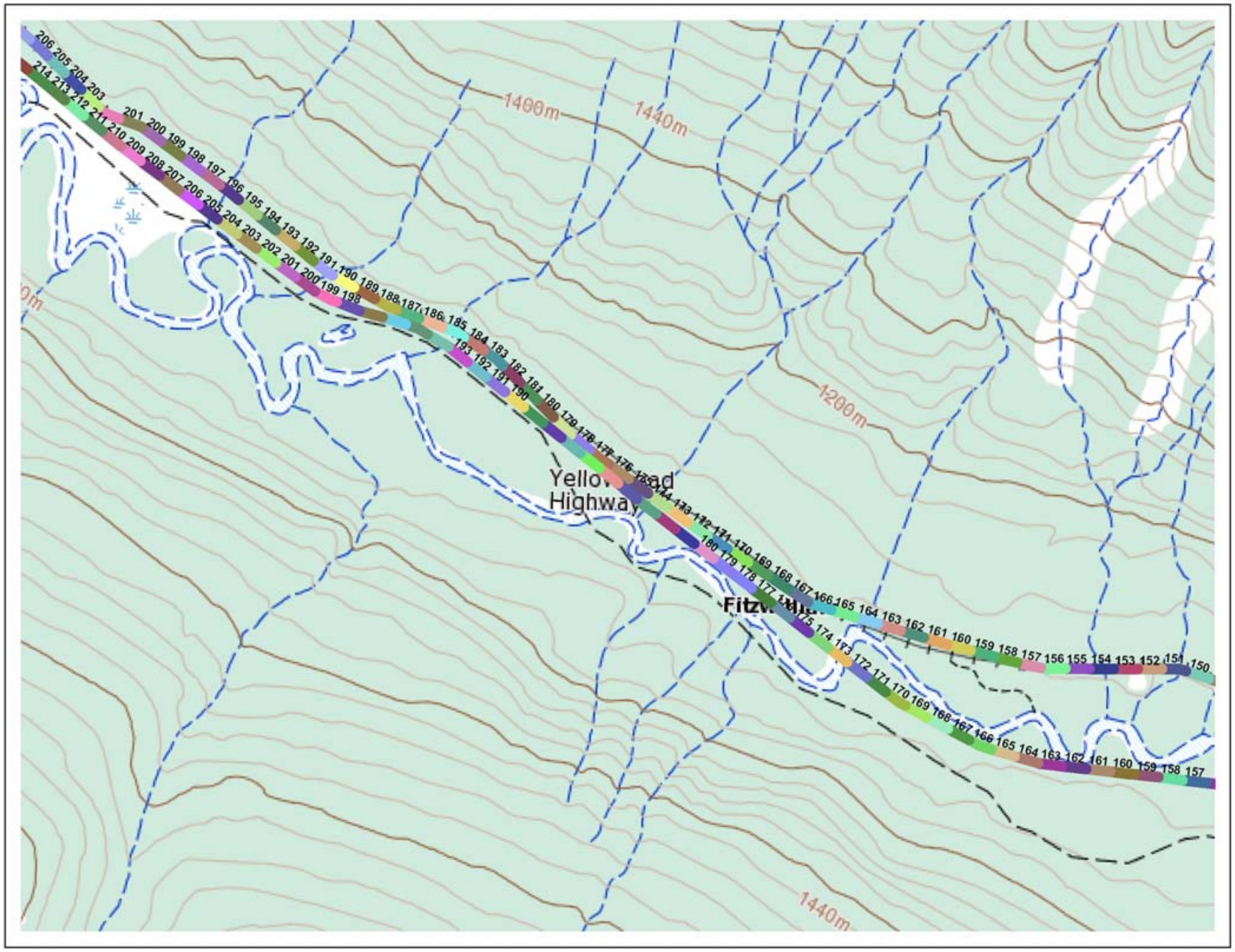
MRPP HWY 16 1-59; RAILROAD ALBREDA 1-50



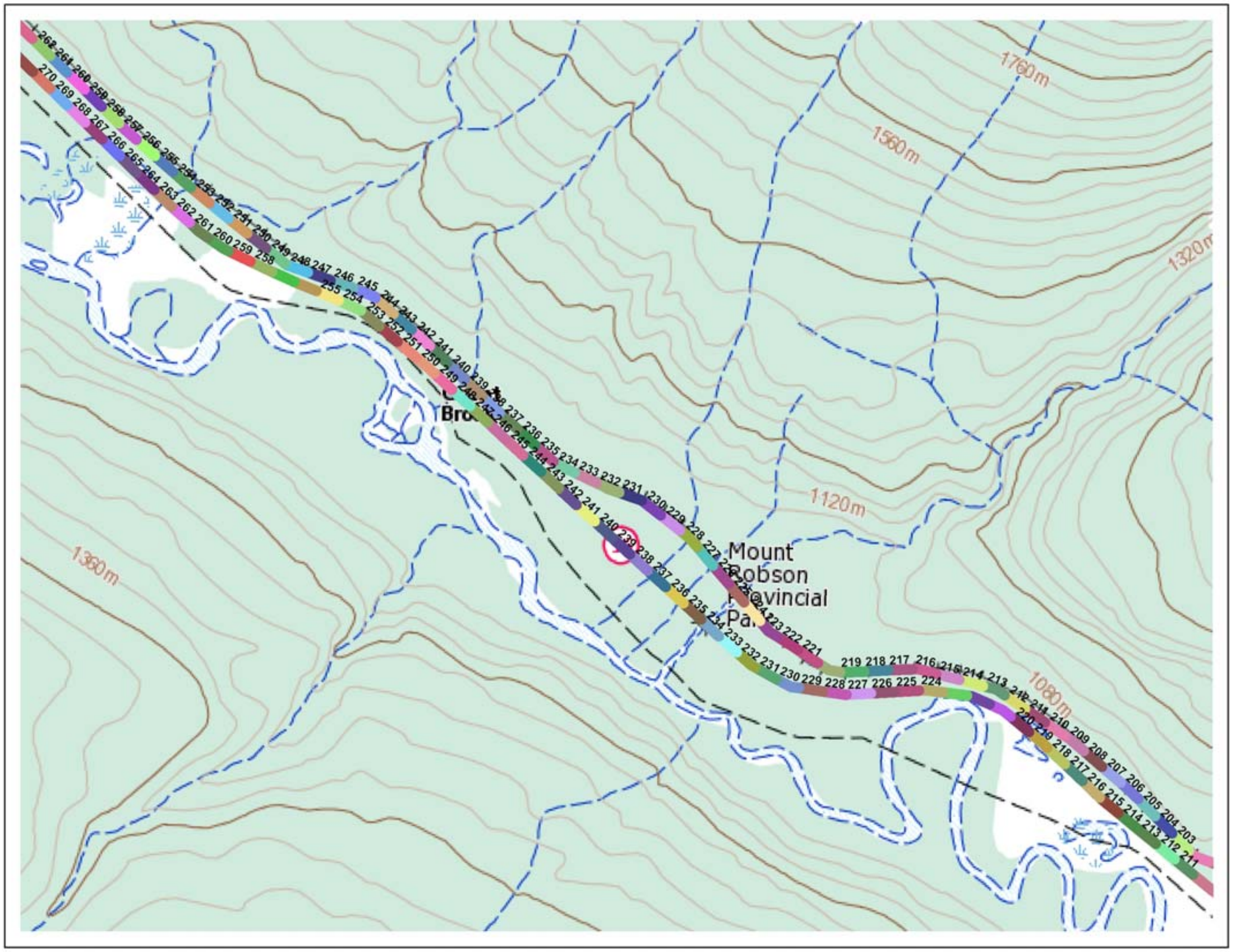
MRPP HWY 16 57-109; RAILROAD ALBREDA 50-100



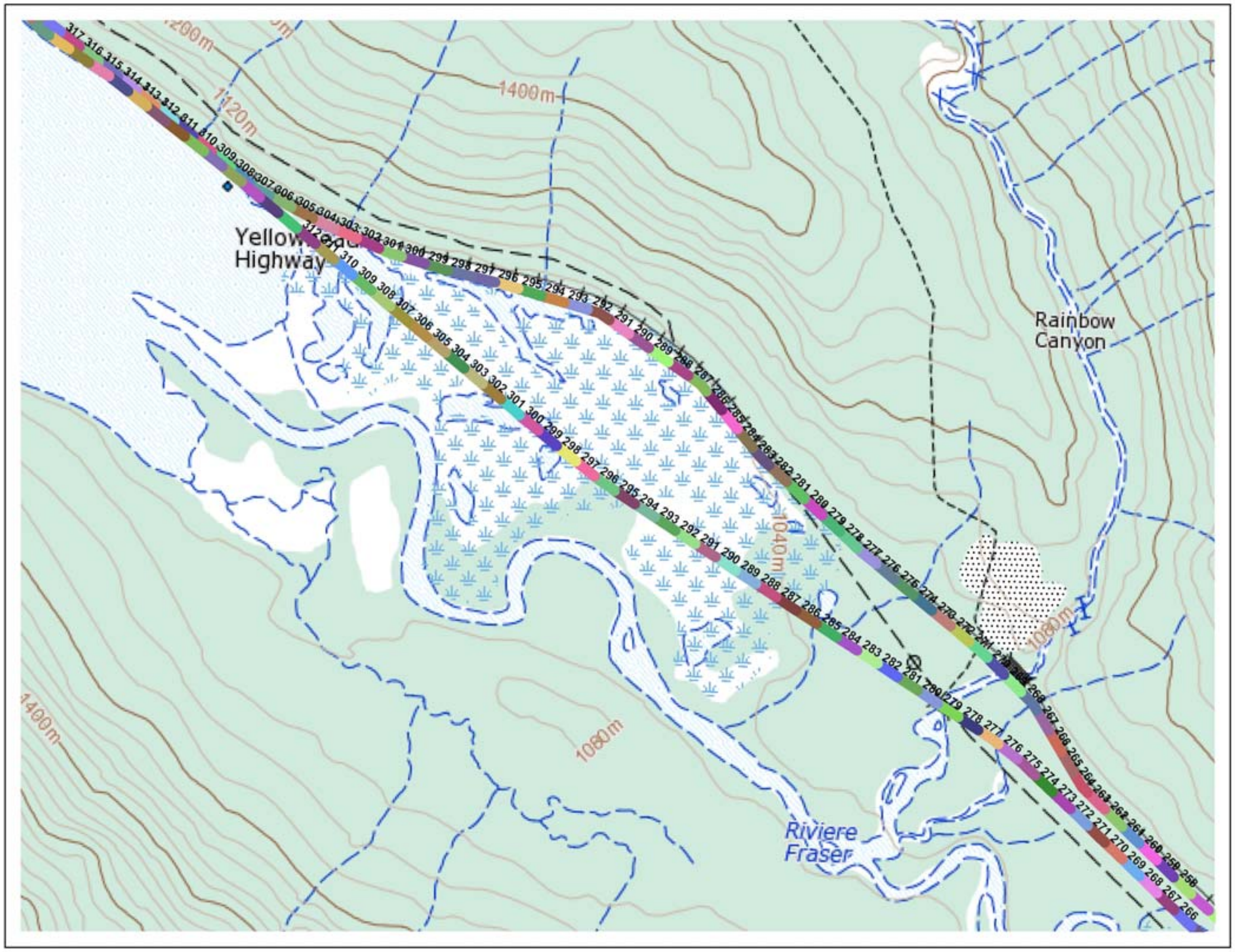
MRPP HWY 16 107-158; RAILROAD ALBREDA 199-152



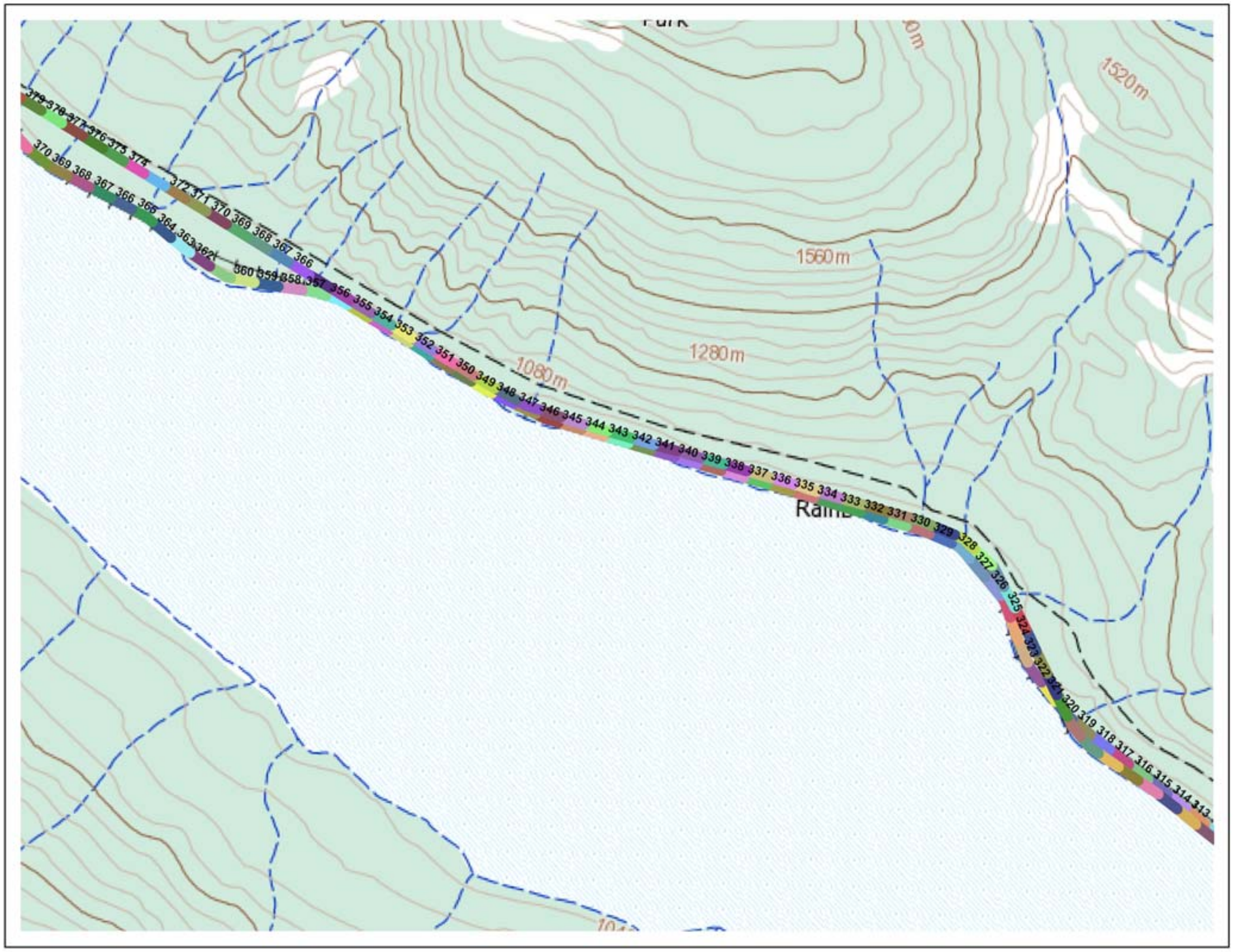
MRPP HWY 16 157-214; RAILROAD ALBREDA 150-206



MRPP HWY 16 211-270; RAILROAD ALBREDA 203-262

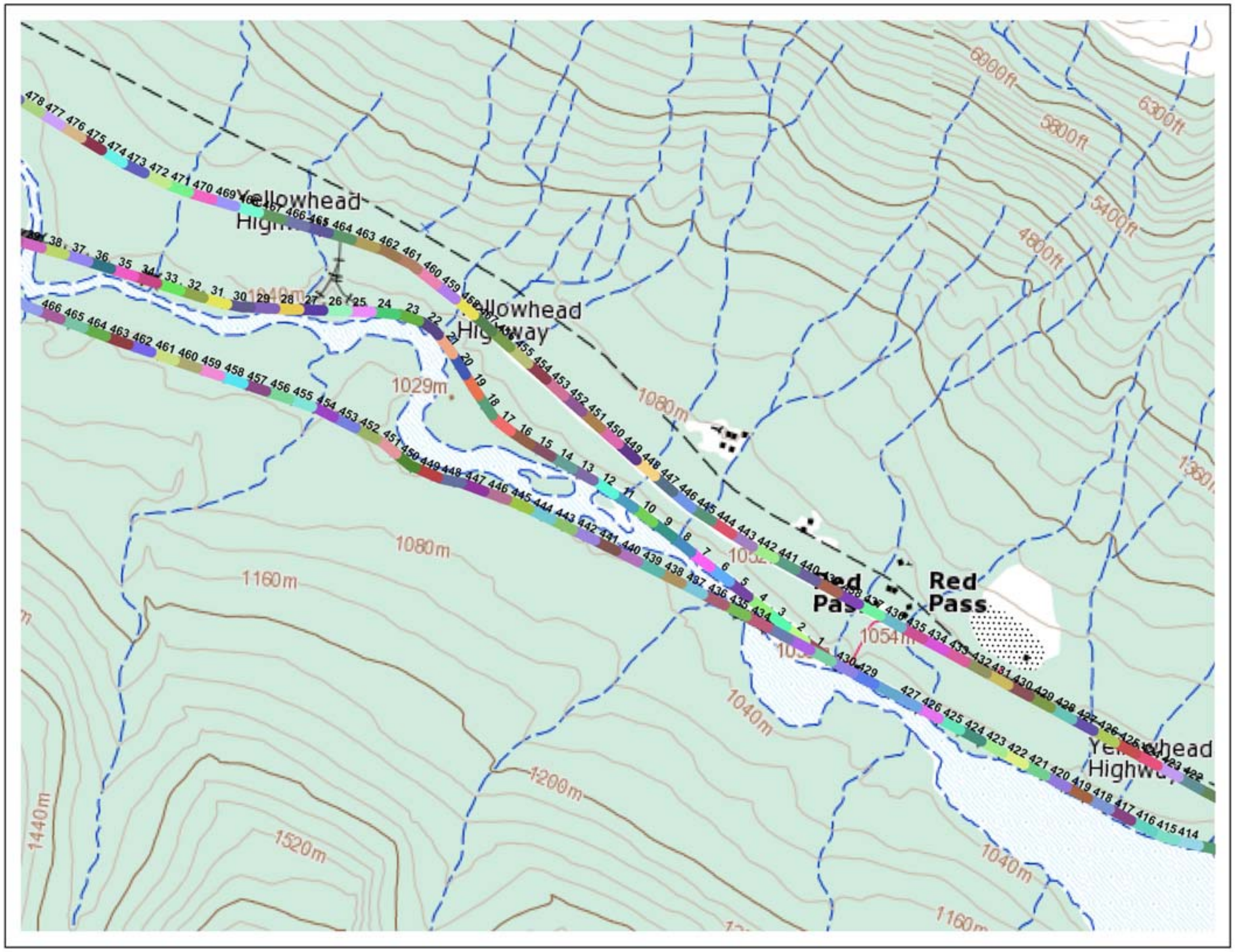


MRPP HWY 16 266-326; RAILROAD ALBREDA 258-317

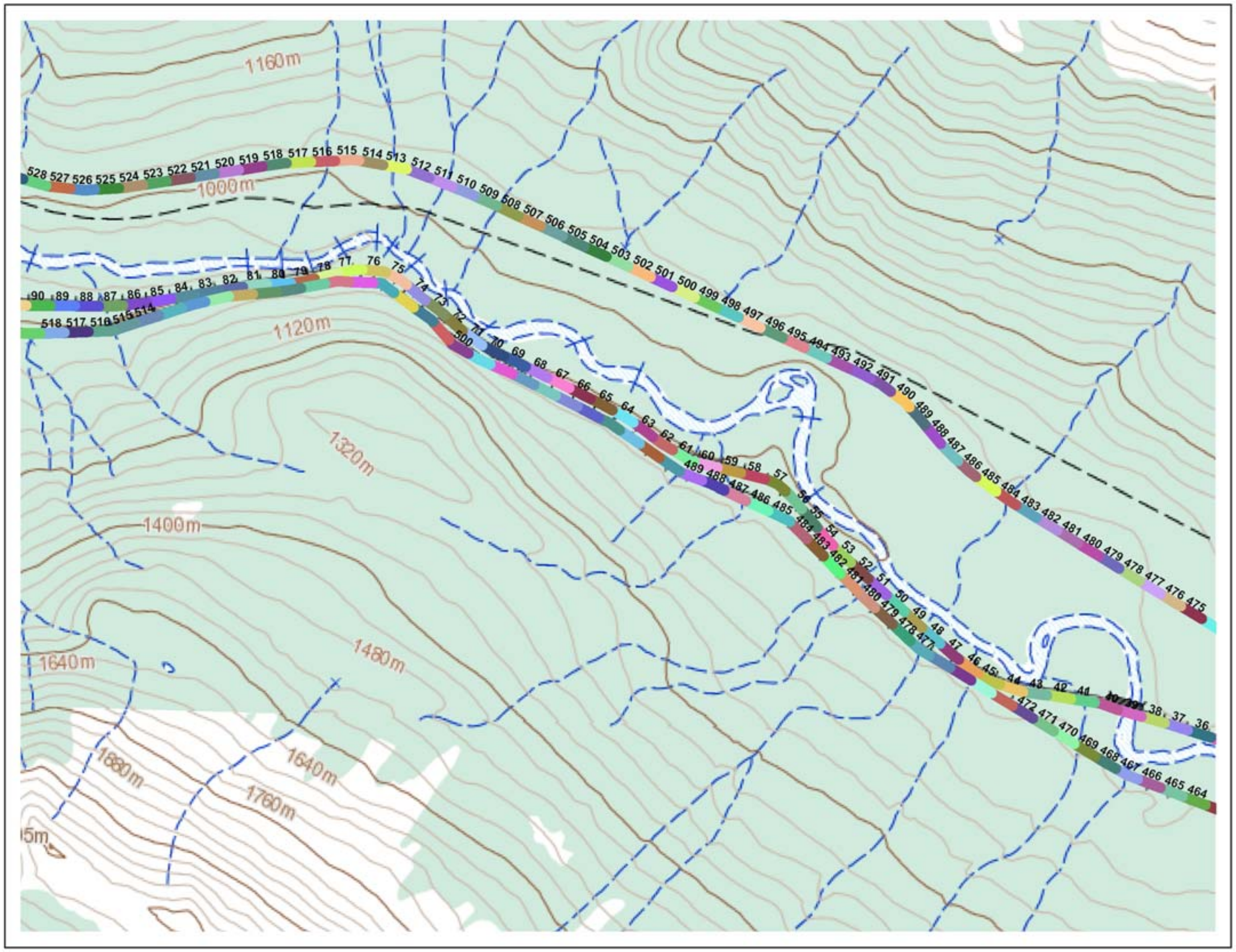


MRPP HWY 16 321-379; RAILROAD ALBREDA 313-370

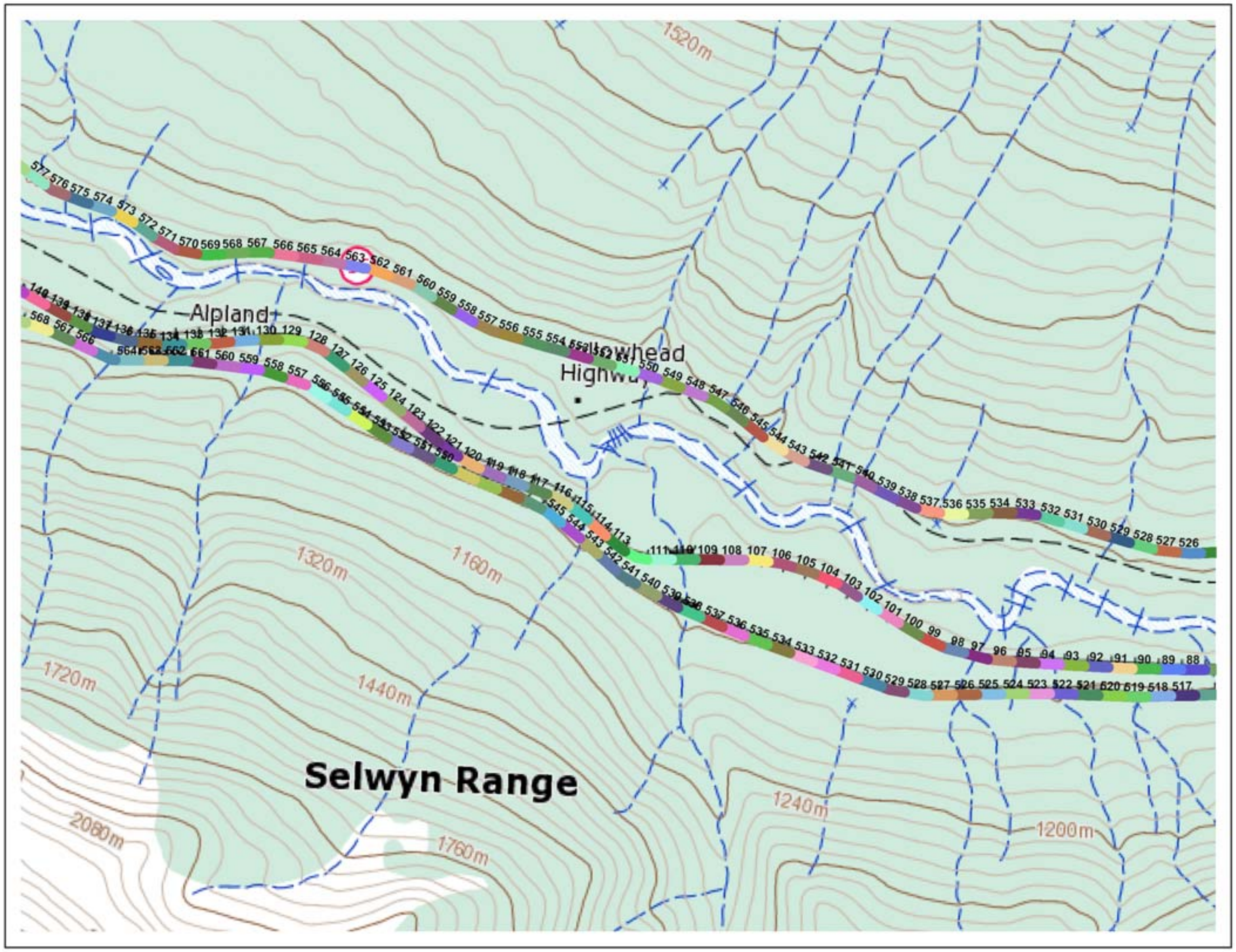
MRPP HWY 16 374-428; RAILROAD ALBREDA 366-420



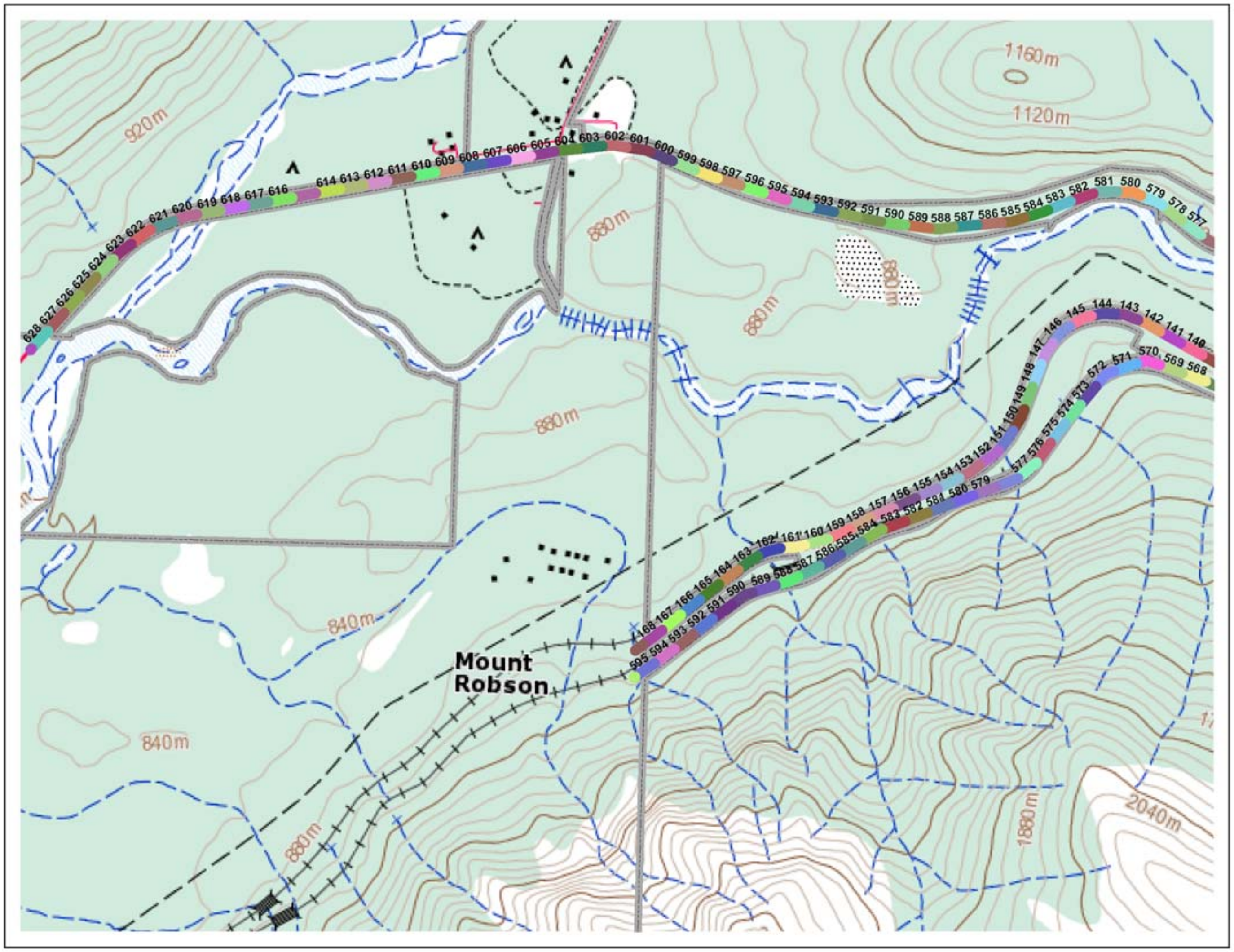
MRPP HWY 16 422-478; RAILROAD ALBREDA 414-466; RAILROAD ROBSON 1-38



MRPP HWY 16 475-528; RAILROAD ALBREDA 464-518; RAILROAD ROBSON 36-90



MRPP HWY 16 526-577; RAILROAD ALBREDA 517-568; RAILROAD ROBSON 88-140



MRPP HWY 16 577-628; RAILROAD ALBREDA 568-595; RAILROAD ROBSON 140-168

17. APPENDIX E: MORTALITY CLUSTERS FOR THE FOCAL SPECIES FOR HWY 16 AND THE RAILROAD THROUGH JNP AND MRPP.

E1. Hwy 16 through JNP.

E2. Hwy 16 through MRPP.

E3. Railroad through JNP.

E4. Railroad, Albreda and Robson section combined, through MRPP.

Red = Mortality cluster for focal species

Blue = Buffer zone (1 km from start or end mortality cluster)

E1. Hwy 16 through JNP.

Hwy_seg	BLAC	COUG	COYO	GRIZ	LYNX	REFO	WOLF	WOLV	Total	Mortality value	Rank
1									0	0	
2									0	2	2.33
3	1		1						2	2	
4									0	3	
5					1				1	1	
6									0	1	
7									0	0	
8									0	0	
9									0	2	
10	1						1		2	2	
11									0	2	
12									0	0	
13									0	0	
14									0	0	
15									0	0	
16									0	0	
17									0	1	
18			1						1	1	
19									0	1	
20									0	0	
21									0	0	
22									0	3	3.00
23			1		1	1			3	3	
24									0	3	
25									0	0	
26									0	1	
27			1						1	1	
28									0	2	
29			1						1	2	
30	1								1	2	
31									0	1	
32									0	0	
33									0	2	
34	1		1						2	2	
35									0	2	
36									0	0	
37									0	1	
38	1								1	1	

39									0	3	2.33
40	1		1						2	2	
41									0	2	
42									0	0	
43									0	1	
44	1								1	1	
45									0	1	
46									0	0	
47									0	0	
48									0	0	
49									0	2	
50	2								2	2	
51									0	2	
52									0	0	
53									0	0	
54									0	0	
55									0	0	
56									0	0	
57									0	2	2.67
58			1				1		2	3	
59	1								1	3	
60									0	1	
61									0	0	
62									0	0	
63									0	0	
64									0	0	
65									0	1	
66	1								1	1	
67									0	1	
68									0	1	
69	1								1	1	
70									0	1	
71									0	0	
72									0	0	
73									0	0	
74									0	0	
75									0	0	
76									0	0	
77									0	1	
78	1								1	5	5.33
79	2		2						4	6	

80	1								1	5	
81									0	1	
82									0	0	
83									0	0	
84									0	0	
85									0	0	
86									0	0	
87									0	2	2.50
88	2								2	3	
89			1						1	3	
90									0	3	
91			2						2	2	
92									0	2	
93									0	0	
94									0	0	
95									0	0	
96									0	0	
97									0	0	
98									0	0	
99									0	0	
100									0	0	
101									0	0	
102									0	0	
103									0	0	
104									0	0	
105									0	0	
106									0	0	
107									0	2	
108	1		1						2	2	
109									0	2	
110									0	0	
111									0	0	
112									0	0	
113									0	0	
114									0	0	
115									0	2	
116	1		1						2	2	
117									0	2	
118									0	2	
119	1		1						2	2	
120									0	2	

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122									0	0	
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124									0	0	
125									0	0	
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128							1		1	5	
129									0	2	
130			1						1	1	
131									0	2	
132	1								1	1	
133									0	1	
134									0	1	
135			1						1	1	
136									0	2	
137						1			1	1	
138									0	1	
139									0	0	
140									0	2	2.33
141	1		1						2	2	
142									0	3	
143	1								1	1	
144									0	2	
145			1						1	1	
146									0	2	
147			1						1	1	
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149									0	1	
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158									0	0	
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161									0	0	

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164						1			1	2	
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166									0	0	
167									0	0	
168									0	0	
169									0	0	
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172									0	1	
173									0	0	
174									0	0	
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186									0	0	
187									0	0	
188									0	3	3.00
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190									0	3	
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198							1		1	2	
199			1						1	2	
200									0	1	
201									0	0	
202									0	1	

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204									0	1	
205									0	0	
206									0	0	
207									0	0	
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214									0	1	
215			1						1	1	
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257								1	1	3	
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272									0	3	
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282	1				1				2	2	
283									0	4	
284			1				1		2	2	

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358			1						1	3	
359							1		1	2	
360									0	1	
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364									0	1	
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366	1		5						6	7	

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376									0	3	
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404							1		1	3	
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406									0	2	
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426	1								1	11	
427			1						1	3	
428			1						1	2	
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447									0	0	
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491									0	2	3.10
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495									0	6	
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497									0	4	
498									0	2	
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502									0	1	
503									0	0	
504									0	2	
505			2						2	2	
506									0	2	
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508			1						1	2	2.71
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511							1		1	3	
512			1						1	3	
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542									0	1	
543									0	0	
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546	1								1	4	
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682									0	0	
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684									0	0	
685									0	0	
686									0	0	
687									0	0	
688									0	1	
689							1		1	1	
690									0	2	
691	1								1	1	
692									0	3	2.33
693			1					1	2	2	
694									0	2	

695									0	1	
696			1						1	1	
697									0	3	2.67
698			2						2	2	
699									0	3	
700			1						1	1	
701									0	1	
702									0	0	
703									0	0	
704									0	0	
705									0	0	
706									0	0	
707									0	1	
708							1		1	1	
709									0	2	2.50
710							1		1	3	
711			1				1		2	3	
712									0	2	
713									0	0	
714									0	0	
715									0	0	
716									0	0	
717									0	2	2.67
718	1						1		2	3	
719			1						1	3	
720									0	1	
721									0	0	
722									0	0	
723									0	0	
724									0	0	
725									0	0	
726									0	0	
727									0	0	
728									0	1	
729							1		1	1	
730									0	1	
731									0	0	
732									0	1	
733							1		1	2	
734			1						1	2	
735									0	1	

736									0	0	
737									0	2	
738			2						2	5	4.33
739			3						3	5	
740									0	3	
741									0	0	
742									0	0	
743									0	1	
744					1				1	2	
745							1		1	2	
746									0	1	
747									0	0	
748									0	1	
749			1						1	1	
750									0	1	
751									0	0	
752									0	0	
753									0	0	
754									0	0	
755									0	0	
756									0	0	
757									0	1	
758					1				1	1	
759									0	1	
760									0	0	
761									0	0	
762									0	0	
763									0	0	
764									0	0	
765									0	0	
766									0	0	
767									0	0	
768									0	0	
769									0	0	
770									0	0	
771									0	0	
772									0	0	
773									0	0	
774									0	0	
775									0	0	
Total	67	1	155	3	10	11	57	3	307		

E2. Hwy 16 through MRPP.

Hwy_seg	BEAR	COYOTE	WOLF	Grand Total	Mortality value	Ranking
1				0	0	
2				0	0	
3				0	0	
4				0	0	
5				0	0	
6				0	0	
7				0	0	
8				0	0	
9				0	0	
10				0	0	
11				0	0	
12				0	0	
13				0	0	
14				0	0	
15				0	0	
16				0	0	
17				0	0	
18				0	0	
19				0	0	
20				0	0	
21				0	0	
22				0	0	
23				0	0	
24				0	0	
25				0	0	
26				0	2	2.00
27			2	2	2	
28				0	2	
29				0	0	
30				0	0	
31				0	0	
32				0	0	
33				0	0	
34				0	0	
35				0	0	
36				0	0	
37				0	0	
38				0	0	

39				0	0	
40				0	0	
41				0	0	
42				0	0	
43				0	0	
44				0	0	
45				0	0	
46				0	0	
47				0	0	
48				0	0	
49				0	0	
50				0	0	
51				0	0	
52				0	0	
53				0	0	
54				0	0	
55				0	0	
56				0	0	
57				0	0	
58				0	0	
59				0	0	
60				0	0	
61				0	0	
62				0	0	
63				0	0	
64				0	0	
65				0	0	
66				0	0	
67				0	0	
68				0	0	
69				0	0	
70				0	0	
71				0	0	
72				0	0	
73				0	0	
74				0	0	
75				0	0	
76				0	0	
77				0	0	
78				0	0	
79				0	0	

80				0	0	
81				0	0	
82				0	0	
83				0	0	
84				0	0	
85				0	0	
86				0	0	
87				0	0	
88				0	0	
89				0	0	
90				0	0	
91				0	0	
92				0	0	
93				0	0	
94				0	0	
95				0	0	
96				0	0	
97				0	0	
98				0	0	
99				0	0	
100				0	0	
101				0	0	
102				0	0	
103				0	0	
104				0	0	
105				0	0	
106				0	0	
107				0	0	
108				0	0	
109				0	0	
110				0	0	
111				0	0	
112				0	0	
113				0	0	
114				0	0	
115				0	0	
116				0	0	
117				0	0	
118				0	0	
119				0	0	
120				0	0	

121				0	0	
122				0	1	
123	1			1	1	
124				0	1	
125				0	0	
126				0	0	
127				0	0	
128				0	0	
129				0	0	
130				0	0	
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144				0	0	
145				0	0	
146				0	0	
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148				0	0	
149				0	0	
150				0	0	
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154				0	0	
155				0	0	
156				0	0	
157				0	0	
158				0	0	
159				0	0	
160				0	0	
161				0	0	

162				0	0	
163				0	0	
164				0	1	
165			1	1	1	
166				0	1	
167				0	0	
168				0	0	
169				0	0	
170				0	0	
171				0	0	
172				0	0	
173				0	0	
174				0	0	
175				0	0	
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177				0	0	
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195				0	0	
196				0	0	
197				0	0	
198				0	0	
199				0	0	
200				0	0	
201				0	0	
202				0	2	1.50

203	2			2	2	
204				0	2	
205				0	1	
206		1		1	1	
207				0	1	
208				0	0	
209				0	0	
210				0	0	
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236				0	0	
237				0	0	
238				0	0	
239				0	0	
240				0	0	
241				0	0	
242				0	0	
243				0	0	

244				0	0		
245				0	0		
246				0	0		
247				0	1		
248	1			1	1		
249				0	1		
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251				0	0		
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276			1	1	1		
277				0	1		
278				0	0		
279				0	0		
280				0	0		
281				0	0		
282				0	1		
283	1			1	1		
284				0	1		

285				0	0	
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287				0	0	
288				0	0	
289				0	0	
290				0	0	
291				0	0	
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293				0	0	
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318				0	0	
319				0	0	
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321				0	0	
322				0	0	
323				0	0	
324				0	0	
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337				0	0	
338				0	0	
339				0	0	
340				0	1	
341		1		1	1	
342				0	1	
343				0	0	
344				0	0	
345				0	0	
346				0	0	
347				0	0	
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358	1			1	1	
359				0	1	
360				0	0	
361				0	0	
362				0	0	
363				0	0	
364				0	0	
365				0	0	
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367				0	0	
368				0	0	
369				0	0	
370				0	0	
371				0	0	
372				0	0	
373				0	0	
374				0	0	
375				0	0	
376				0	0	
377				0	0	
378				0	0	
379				0	0	
380				0	0	
381				0	2	2.25
382	2			2	3	
383	1			1	3	
384				0	1	
385				0	0	
386				0	0	
387				0	0	
388				0	0	
389				0	0	
390				0	0	
391				0	0	
392				0	0	
393				0	0	
394				0	0	
395				0	0	
396				0	0	
397				0	0	
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400				0	0	
401				0	0	
402				0	0	
403				0	0	
404				0	0	
405				0	0	
406				0	0	
407				0	0	

408				0	0	
409				0	0	
410				0	0	
411				0	0	
412				0	0	
413				0	0	
414				0	0	
415				0	0	
416				0	0	
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418				0	0	
419				0	0	
420				0	0	
421				0	0	
422				0	0	
423				0	0	
424				0	0	
425				0	0	
426				0	0	
427				0	0	
428				0	0	
429				0	0	
430				0	0	
431				0	0	
432				0	0	
433				0	0	
434				0	1	
435	1			1	1	
436				0	1	
437				0	0	
438				0	0	
439				0	0	
440				0	0	
441				0	0	
442				0	0	
443				0	0	
444				0	0	
445				0	0	
446				0	0	
447				0	0	
448				0	0	

449				0	0	
450				0	0	
451				0	0	
452				0	0	
453				0	0	
454				0	0	
455				0	0	
456				0	0	
457				0	0	
458				0	0	
459				0	0	
460				0	0	
461				0	0	
462				0	0	
463				0	0	
464				0	0	
465				0	0	
466				0	1	
467			1	1	1	
468				0	1	
469				0	0	
470				0	0	
471				0	0	
472				0	0	
473				0	0	
474				0	0	
475				0	1	
476			1	1	1	
477				0	1	
478				0	0	
479				0	0	
480				0	0	
481				0	0	
482				0	0	
483				0	0	
484				0	0	
485				0	0	
486				0	0	
487				0	0	
488				0	0	
489				0	0	

490				0	0	
491				0	0	
492				0	0	
493				0	0	
494				0	0	
495				0	0	
496				0	1	
497	1			1	1	
498				0	1	
499				0	0	
500				0	0	
501				0	0	
502				0	0	
503				0	0	
504				0	0	
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506				0	0	
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513				0	0	
514				0	0	
515				0	0	
516				0	0	
517				0	1	
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519				0	1	
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521				0	0	
522				0	0	
523				0	0	
524				0	0	
525				0	0	
526				0	0	
527				0	0	
528				0	0	
529				0	0	
530				0	0	

531				0	0	
532				0	0	
533				0	0	
534				0	0	
535				0	0	
536				0	0	
537				0	0	
538				0	0	
539				0	0	
540				0	0	
541				0	0	
542				0	0	
543				0	0	
544				0	0	
545				0	0	
546				0	0	
547				0	0	
548				0	0	
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559				0	0	
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561				0	0	
562				0	0	
563				0	0	
564				0	0	
565				0	0	
566				0	0	
567				0	0	
568				0	0	
569				0	0	
570				0	0	
571				0	0	

572				0	0	
573				0	0	
574				0	0	
575				0	0	
576				0	0	
577				0	0	
578				0	0	
579				0	0	
580				0	0	
581				0	0	
582				0	0	
583				0	0	
584				0	0	
585				0	0	
586				0	0	
587				0	0	
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602				0	0	
603				0	0	
604				0	0	
605				0	0	
606				0	0	
607				0	0	
608				0	0	
609				0	0	
610				0	0	
611				0	0	
612				0	0	

613				0	2	2.00
614	2			2	2	
615				0	2	
616				0	0	
617				0	0	
618				0	0	
619				0	0	
620				0	0	
621				0	0	
622				0	0	
623				0	0	
624				0	0	
625				0	0	
626				0	0	
627				0	0	
628				0	0	
Grand Total	14	2	6	22		

E3. Railroad through JNP.

Railway_seg	BLAC	COYO	GRIZ	REFO	WOLF	WOLV	Total	Value	Rank
1	3						3	3	3.00
2							0	5	
3	2						2	2	
4							0	2	
5							0	0	
6							0	0	
7							0	1	
8	1						1	1	
9							0	1	
10							0	0	
11							0	0	
12							0	1	
13	1						1	1	
14							0	1	
15							0	0	
16							0	1	
17	1						1	1	
18							0	1	
19							0	0	
20							0	0	
21							0	0	
22							0	0	
23							0	0	
24							0	1	
25	1						1	1	
26							0	1	
27							0	0	
28							0	0	
29							0	0	
30							0	0	
31							0	0	
32							0	0	
33							0	1	
34	1						1	1	
35							0	1	
36							0	0	
37							0	0	
38							0	1	
39					1		1	1	

40							0	1	
41							0	0	
42							0	0	
43							0	0	
44							0	0	
45							0	0	
46							0	0	
47							0	0	
48							0	0	
49							0	0	
50							0	0	
51							0	0	
52							0	0	
53							0	0	
54							0	0	
55							0	1	
56	1						1	1	
57							0	1	
58							0	0	
59							0	0	
60							0	0	
61							0	0	
62							0	0	
63							0	0	
64							0	0	
65							0	0	
66							0	0	
67							0	0	
68							0	1	
69					1		1	1	
70							0	1	
71							0	0	
72							0	1	
73	1						1	1	
74							0	1	
75							0	0	
76							0	0	
77							0	0	
78							0	0	
79							0	0	
80							0	0	

81							0	0	
82							0	0	
83							0	0	
84							0	0	
85							0	0	
86							0	0	
87							0	0	
88							0	0	
89							0	0	
90							0	0	
91							0	0	
92							0	0	
93							0	1	
94						1	1	1	
95							0	1	
96							0	0	
97							0	0	
98							0	0	
99							0	1	1.13
100	1						1	1	
101							0	1	
102							0	1	
103	1						1	1	
104							0	2	
105					1		1	1	
106							0	1	
107							0	0	
108							0	0	
109							0	1	2.67
110	1						1	5	
111	4						4	5	
112							0	6	
113	1		1				2	2	
114							0	2	
115							0	1	
116	1						1	1	
117							0	1	
118							0	0	
119							0	0	
120							0	0	
121							0	0	

122							0	0	
123							0	0	
124							0	0	
125							0	0	
126							0	0	
127							0	0	
128							0	0	
129							0	0	
130							0	1	
131					1		1	1	
132							0	1	
133							0	0	
134							0	0	
135							0	1	
136	1						1	1	
137							0	1	
138							0	0	
139							0	0	
140							0	0	
141							0	0	
142							0	1	
143						1	1	1	
144							0	1	
145							0	0	
146							0	0	
147							0	0	
148							0	0	
149							0	0	
150							0	0	
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496							0	2	1.80
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717							0	4	3.50
718			4				4	4	
719							0	4	
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770							0	1	
771							0	0	
772							0	0	
773							0	0	
774							0	0	
775							0	0	
Grand Total	64	2	14	1	19	2	102		

E4. Railroad, Albreda and Robson section combined, through MRPP.

Railroad	Railway_seg	BLAC	WOLF	Grand Total	Mortality value	Ranking
Albreda	1			0	0	
Albreda	2			0	0	
Albreda	3			0	0	
Albreda	4			0	0	
Albreda	5			0	0	
Albreda	6			0	0	
Albreda	7			0	0	
Albreda	8			0	0	
Albreda	9			0	0	
Albreda	10			0	0	
Albreda	11			0	0	
Albreda	12			0	0	
Albreda	13			0	0	
Albreda	14			0	0	
Albreda	15			0	0	
Albreda	16			0	0	
Albreda	17			0	0	
Albreda	18			0	0	
Albreda	19			0	0	
Albreda	20			0	0	
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Albreda	22			0	0	
Albreda	23			0	0	
Albreda	24			0	0	
Albreda	25			0	0	
Albreda	26			0	0	
Albreda	27			0	0	
Albreda	28			0	0	
Albreda	29			0	0	
Albreda	30			0	0	
Albreda	31			0	0	
Albreda	32			0	0	
Albreda	33			0	0	
Albreda	34			0	0	
Albreda	35			0	0	
Albreda	36			0	0	
Albreda	37			0	0	
Albreda	38			0	0	

Albreda	39			0	0	
Albreda	40			0	0	
Albreda	41			0	0	
Albreda	42			0	0	
Albreda	43			0	0	
Albreda	44			0	0	
Albreda	45			0	0	
Albreda	46			0	0	
Albreda	47			0	0	
Albreda	48			0	0	
Albreda	49			0	0	
Albreda	50			0	0	
Albreda	51			0	0	
Albreda	52			0	0	
Albreda	53			0	1	1
Albreda	54	1		1	1	
Albreda	55			0	1	
Albreda	56			0	0	
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Albreda	71			0	0	
Albreda	72			0	0	
Albreda	73			0	0	
Albreda	74			0	0	
Albreda	75			0	0	
Albreda	76			0	0	
Albreda	77			0	0	
Albreda	78			0	0	
Albreda	79			0	0	

Albreda	80			0	0	
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Albreda	82			0	0	
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Albreda	84			0	0	
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Albreda	130			0	1	
Albreda	131			0	0	
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Albreda	156			0	0	
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Albreda	158			0	0	
Albreda	159			0	0	
Albreda	160			0	0	
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Albreda	171			0	0	
Albreda	172			0	0	
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Total		2	2	4		

18. APPENDIX F: MORTALITY CLUSTERS FOR THE FOCAL SPECIES FOR HWY 16 AND THE RAILROAD THROUGH JNP AND MRPP (EXCLUDING RED FOX AND COYOTE).

F1. Hwy 16 through JNP.

Hwy_seg	BLAC	COUG	GRIZ	LYNX	WOLF	WOLV	Total	Value	Rank
1							0	0	
2							0	1	1.20
3	1						1	1	
4							0	2	
5				1			1	1	
6							0	1	
7							0	0	
8							0	0	
9							0	2	2.00
10	1				1		2	2	
11							0	2	
12							0	0	
13							0	0	
14							0	0	
15							0	0	
16							0	0	
17							0	0	
18							0	0	
19							0	0	
20							0	0	
21							0	0	
22							0	1	
23				1			1	1	
24							0	1	
25							0	0	
26							0	0	
27							0	0	
28							0	0	
29							0	1	
30	1						1	1	
31							0	1	
32							0	0	
33							0	1	
34	1						1	1	

35							0	1	
36							0	0	
37							0	1	1.20
38	1						1	1	
39							0	2	
40	1						1	1	
41							0	1	
42							0	0	
43							0	1	
44	1						1	1	
45							0	1	
46							0	0	
47							0	0	
48							0	0	
49							0	2	2.00
50	2						2	2	
51							0	2	
52							0	0	
53							0	0	
54							0	0	
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277					1		1	4	
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566					2		2	2	
567							0	2	

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576							0	1	2.50
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578	1				2		3	4	
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635					1		1	2	
636				1			1	4	
637	2						2	3	
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645							0	1	1.50
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667	2						2	2	
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674							0	0	
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688							0	1	1.29
689					1		1	1	
690							0	2	

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717							0	2	2.00
718	1				1		2	2	
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739							0	0	
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741							0	0	
742							0	0	
743							0	1	1.50
744				1			1	2	
745					1		1	2	
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771							0	0	
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773							0	0	
774							0	0	
775							0	0	
Total	67	1	3	10	57	3	141		

F2. Hwy 16 through MRPP.

Hwy_seg	BEAR	WOLF	Grand Total	Mortality value	Rank
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2			0	0	
3			0	0	
4			0	0	
5			0	0	
6			0	0	
7			0	0	
8			0	0	
9			0	0	
10			0	0	
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13			0	0	
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16			0	0	
17			0	0	
18			0	0	
19			0	0	
20			0	0	
21			0	0	
22			0	0	
23			0	0	
24			0	0	
25			0	0	
26			0	2	2.00
27		2	2	2	
28			0	2	
29			0	0	
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31			0	0	
32			0	0	
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36			0	0	
37			0	0	
38			0	0	

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45			0	0	
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Grand Total	14	6	20		

F3. Railroad through JNP.

Railway_seg	BLAC	GRIZ	WOLF	WOLV	Total	Value	Excl rank
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653					0	2	2.00
654	2				2	2	
655					0	2	
656					0	0	
657					0	0	
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662	1				1	2	
663					0	2	
664	1				1	1	
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674					0	1	
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680			1		1	1	
681					0	1	
682					0	0	
683					0	0	
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695					0	0	
696					0	0	
697					0	1	
698			1		1	1	
699					0	1	
700					0	0	
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704		1			1	1	
705					0	1	
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707					0	1	
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714					0	0	
715					0	0	
716					0	0	
717					0	4	3.00

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719					0	4	
720					0	2	
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763					0	0	
764					0	0	
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766					0	0	
767					0	0	
768					0	1	
769			1		1	1	
770					0	1	
771					0	0	
772					0	0	
773					0	0	
774					0	0	
775					0	0	
Grand Total	64	14	19	2	99		

F4. Railroad, Albreda and Robson section combined, through MRPP.

Red fox, and coyote were not recorded along the railroad in MRPP. Therefore this table is identical to that in Appendix E4.

Red = Mortality cluster for focal species

Blue = Buffer zone (1 km from start or end mortality cluster)

19. APPENDIX G: ALL OBSERVATIONS (DEAD AND ALIVE) OF ALL FOCAL SPECIES AND SELECTED OTHER SPECIES WITHIN 200 M FROM HWY 16 AND THE RAILROAD THROUGH JNP

G1. Hwy 16 through JNP.

G2. Railroad through JNP.

G1. Hwy 16 through JNP.

Hwy_seg	BEAR	BLAC	CARI	COUG	COYO	DEER	ELK	FOX	GOAT	GRIZ	LYNX	MOOS	MULE	REFO	SHEE	WHIT	WOLF	WOLV	Total	Observation value	Ranking
1		3		1	5		5				2	4			223	5			248	315	251.33
2				1						2		6	2		52	4			67	335	
3		7			1		2			1		1	1		5	2			20	104	
4												1	1		11	1	3		17	71	
5		1		1		1					1		5		22	3			34	58	
6		1										1	2			3			7	44	
7							1						2						3	11	
8												1							1	15	
9		4					7												11	400	416.67
10		2			2		17					8	46		309	3	1		388	402	
11													1			2			3	448	
12							57												57	60	
13																			0	60	
14												1	1			1			3	6	
15		1											2						3	7	
16													1						1	14	
17							1						3		1	5			10	20	
18					3								2			4			9	22	
19													2			1			3	17	

20												3	1			1			5	156	
21					1		59								83	5			148	161	
22		1					1										6		8	180	
23		1			1		1				1	1	6	1	2	10			24	89	
24							32					3	21			1			57	84	
25													1			2			3	60	
26																			0	6	
27					1								2						3	7	
28					1							1	1			1			4	44	
29					1		31						3			2			37	44	
30		1														2			3	45	
31		1														4			5	11	
32							1									2			3	13	
33		1											2			2			5	57	
34		1		1	1		41									4	1		49	54	
35																			0	56	
36		4										1				1	1		7	9	
37													2						2	11	
38		1														1			2	6	
39							1									1			2	22	
40		1			1							1	1		12	2			18	21	
41													1						1	20	
42																1			1	2	
43																			0	11	
44		5			1							1	1			2			10	14	
45													2			2			4	35	
46							21												21	26	
47																1			1	22	
48																			0	11	
49		3										1				6			10	20	

50		2											5			3			10	28	
51							3					1				4			8	26	
52													5			3			8	39	
53							20									3			23	41	
54													2			8			10	36	
55		1											1			1			3	20	
56							4					1				2			7	32	
57						1	16					1	3			1			22	84	
58					1		48					1				3	2		55	96	
59		1			2		4					3	2			1	6		19	80	
60							0						1			5			6	27	
61													1			1			2	11	
62																1	2		3	8	
63					1		1					1							3	7	
64																1			1	8	
65							1									3			4	107	
66		5		1	1		83					7	3			2			102	106	
67																			0	107	
68		1					1			1		2							5	45	
69		2			1	2	28					1				6			40	49	
70		1										1	1				1		4	51	
71							5					1	1						7	23	
72		1					8					3							12	29	
73							1					6				3			10	30	
74							1						1			4	2		8	27	
75		3			1								2			2	1		9	33	
76		12										1				3			16	56	
77		4					24			2		1							31	107	
78		3					53						1			3			60	114	
79		7			2	3						1	4			6			23	99	

80		4			2							3				7			16	89	
81		19		1	1		4			5		7	1		1	8	3		50	87	
82		1					11						2			7			21	100	
83		4					7					7				6	5		29	145	
84					1		81					3	4		2	4			95	126	
85							1									1			2	105	
86		4			2		1									1			8	35	
87							19		5							1			25	54	
88		3				1	2						2			9	4		21	86	
89		1			2		32									4	1		40	61	
90																			0	49	
91		4			2							2	1						9	114	185.83
92							104					1							105	114	
93																			0	114	
94												1	7			1			9	252	
95		1			2		49					4	67		119		1		243	263	
96					1		5					3	1			1			11	258	
97							1						1			2			4	17	
98																1	1		2	19	
99							1						2		10				13	16	
100																1			1	43	
101							28									1			29	42	
102		1								1						3	7		12	44	
103					2		1												3	15	
104																			0	10	
105		1					4									2			7	10	
106							1									2			3	35	
107						1	22						1			1			25	31	
108		1			1								1						3	90	
109							57						2			3			62	70	

110		1					1						1		1	1			5	81	
111					1		8						5						14	22	
112							1						1			1			3	20	
113													1			2			3	9	
114							2						1						3	9	
115							1								2				3	166	427.28
116		2			1		102								55				160	184	
117							8								12	1			21	247	
118													1		65				66	235	
119		1			1								1		145				148	410	
120							4		28				1		162	1			196	533	
121							5		7						176	1			189	536	
122		1					74		12						64				151	426	
123									4						82				86	445	
124				1					4						203				208	393	
125							2		9						88				99	365	
126							2		12						44		0		58	281	
127		2			3	1	4		38				8		60	7	1		124	227	
128							21		22								2		45	196	
129							21		4				1				1		27	120	
130					1		3		6			1	4		33				48	209	
131							6								127	1			134	244	
132		1					50		8	1					2				62	307	
133				1			58								52				111	223	
134							1								49				50	954	
135		1			3		255		66			1	14		453				793	864	
136							3								18				21	897	
137							1						4	1	77				83	155	
138							22								29				51	159	
139							1								24				25	246	

140							22								148				170	362	
141		1		1	1		85						1		75	3			167	584	
142					1		20						1		224	1			247	536	
143		1					63								57	1			122	445	
144							63								12	1			76	1005	
145		1		2	7		107	2	67	1	1	3	11		595	1	8	1	807	889	
146													5			1			6	830	
147					1		13					1	1			1			17	42	
148					1		16					1	1						19	71	
149					1		28									5	1		35	88	
150		1			1		27					1	1			3			34	83	
151							12									2			14	51	
152							1			1			1						3	150	
153							132									1			133	139	
154					1											1	1		3	159	
155					1		16			3					1	1	1		23	28	
156							1						1						2	45	
157							17						2			1			20	55	
158	1	1					4						5		19	3			33	76	
159							21					1	1						23	188	243.63
160							130						2						132	185	
161							26						3			1			30	223	
162							59						2						61	134	
163					1		30						8		2	1	1		43	361	
164							240						1	1	2	8	5		257	390	
165							89					1							90	361	
166						1	2					3	4			1	3		14	107	
167		1										1	1						3	36	
168							16						3						19	31	
169							6						2		1				9	36	

170					1		2					2				2	1		8	23	
171					1		1						2			2			6	21	
172												1	6						7	13	
173																			0	39	
174							31									1			32	109	152.70
175							76						1						77	179	
176							66					1	1			1	1		70	193	
177					1		22					7	13			2	1		46	121	
178							1					1	1			2			5	131	
179							77					3							80	112	
180					2		18					2	1			4			27	191	
181							79					1	3			1			84	184	
182					2		69									1	1		73	185	
183							26						1			1			28	122	
184					1		17						1			1	1		21	52	
185							1						2						3	29	
186							5												5	8	
187																			0	15	
188							7						3						10	22	
189					2		1					1	2	1		4	1		12	22	
190																			0	13	
191																1			1	2	
192							1												1	6	
193							1					1	2						4	22	
194		1					16												17	25	
195							4												4	22	
196													1						1	6	
197																1			1	88	
198							72						4				10		86	112	
199					1		22						2						25	111	

200																			0	66	
201							30						9			2			41	44	
202													3						3	68	
203					1		12					1	1				9		24	29	
204												2							2	29	
205							2						1						3	74	
206							68						1						69	77	
207							3						2						5	80	
208							6												6	22	
209					1		5									5			11	22	
210							1						2		1	1			5	19	
211													3						3	11	
212					2								1						3	8	
213							1					1							2	5	
214																			0	5	
215					1		2												3	9	
216							6												6	33	
217							21						1		1		1		24	34	
218							2									1	1		4	56	
219							26					2							28	60	
220							28												28	57	
221							1												1	110	
222					1		32						3		42	3			81	87	
223							3					1					1		5	150	
224							59					1	3				1		64	81	
225					2		9									1			12	77	
226							1												1	23	
227							3						7						10	80	
228							68								1				69	86	
229					1	1	3						1		1				7	77	

230							1										0		1	13	
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237													1		160	1			162	301	
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239															47		1		48	137	
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366		4			6		48						9		1	11	1		80	159	
367							32												32	259	
368					2		144									1			147	237	
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376							8												8	64	
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400					1		118			2						3	5		129	263	
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407					1		554			1							8		564	774	
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661												1							1	5	
662							1					3							4	7	
663												2							2	9	
664							2					1							3	6	
665												1							1	6	
666												1					1		2	13	
667		4					1					4					1		10	12	
668																			0	10	
669																			0	0	
670																			0	1	
671												1							1	19	
672		1					2				1	13	1						18	22	
673												3							3	22	
674		1																	1	7	
675		1										2							3	4	
676																			0	11	
677							1			1	1	3	1					1	8	10	
678		1										1							2	12	
679							1					1							2	11	

680							5				1	1							7	18	
681		1					3					3					2		9	30	
682							1									2	11		14	26	
683		1					1					1							3	21	
684		2					1			1									4	13	
685							3					3							6	16	
686							2				1	2				1			6	30	
687			4		2					2		8	1			1			18	35	
688							6			1	1	3							11	32	
689												2					1		3	14	
690																			0	5	
691		1										1							2	14	
692							3										9		12	31	
693					1		4			1		8	1				1	1	17	34	
694												2				3			5	24	
695												2							2	8	
696					1														1	45	
697		2					20			2		14	2			2			42	46	
698					2							1							3	51	
699							4					2							6	10	
700					1														1	9	
701												2							2	14	
702		1					1					9							11	45	
703							16			1		14				1			32	49	
704							1					5							6	39	
705										1									1	13	
706												6							6	11	
707					1								1			2			4	20	
708												9					1		10	26	
709										1		11							12	30	

710					2		1					4					1		8	39	
711		3			4							10					2		19	31	
712							3					1							4	32	
713												5					4		9	25	
714		3										8				1			12	24	
715							1					1	1						3	20	
716							2					3							5	13	
717							4			1									5	20	
718		1					5					3					1		10	20	
719					1					1		3							5	17	
720												2							2	28	
721		1					11			4		4				1			21	31	
722							5					3							8	39	
723							2									1	7		10	27	
724		2					3				2	1					1		9	23	
725							4												4	13	
726																			0	6	
727												1	1						2	11	
728		3					3					2					1		9	51	
729		6		1			27				1	1					4		40	51	
730	1						1												2	59	
731					1		12			4									17	20	
732																	1		1	56	
733							10					1		1			26		38	112	135.13
734		5			5		33			3	1	3	9				14		73	129	
735		1					15				1	1							18	133	
736		2					21			6	1	6					6		42	88	
737		6			1		7			1		2				4	7		28	96	
738		6			2		4					4	3			3	4		26	198	
739		21			7		77			3	1	8	4			3	19	1	144	175	

740		2									0	2						1	5	150	
741							0				1								1	9	
742												2				1			3	4	
743																			0	16	
744							8			1	1	2					1		13	15	
745										1							1		2	24	
746							9												9	11	
747																			0	10	
748												1							1	49	
749		1			1		24			1		14	1				6		48	49	
750																			0	49	
751												1							1	4	
752	1						2												3	4	
753																			0	20	
754		1					1				1	12					2		17	19	
755												2							2	19	
756																			0	2	
757																			0	5	
758							2				1	1				1			5	5	
759																			0	5	
760																			0	0	
761																			0	0	
762																			0	3	
763												3							3	10	
764		1										4				2			7	10	
765																			0	7	
766																			0	2	
767												2							2	6	
768		2			1								1						4	6	
769																			0	4	

770																			0	0	
771																			0	0	
772																			0	0	
773																			0	6	
774		2					2			1	1								6	6	
775																			0	6	
Grand Total	10	521	4	31	674	33	18476	5	324	262	34	811	2291	22	14423	617	627	6			

G2. Railroad through JNP.

Railway_seg	BEAR	BLAC	COUG	COYO	DEER	ELK	FOX	GOAT	GRIZ	LYNX	MOOS	MULE	REFO	SHEE	WHIT	WOLF	WOLV	Total	Observation value	Ranking
1		7									3	1		126	1	1		139	206	623.67
2		1												66				67	1656	
3		2	6	7		17		7		2	4	4		1399		2		1450	1568	
4														51				51	1543	
5				1										41				42	173	
6														80				80	170	
7														48				48	165	
8		1												36				37	85	
9																		0	47	
10											1			9				10	10	
11																		0	29	
12														19				19	20	
13		1																1	20	
14																		0	51	
15														50				50	58	
16														8				8	76	
17		2												16				18	31	
18											3			2				5	23	
19																		0	9	
20											1			3				4	4	
21																		0	9	
22														5				5	7	
23														2				2	8	
24														1				1	906	906.33
25		1	3			8					1			887	1	2		903	907	
26	1													1		1		3	906	
27																		0	7	

28						0								4				4	7	
29				1										2				3	7	
30																		0	3	
31																		0	1	
32						1												1	1	
33																		0	28	
34		1				26												27	28	
35						1												1	29	
36												1						1	2	
37																		0	1	
38																		0	10	
39		3				1					1			4		1		10	60	
40						21								29				50	60	
41																		0	52	
42		1									1							2	2	
43																		0	2	
44																		0	2	
45						2												2	9	
46		2				3					2							7	11	
47						2												2	9	
48																		0	11	
49						7					2							9	10	
50						1												1	21	
51						10						1						11	16	
52		1				1					1	1						4	19	
53									1						1	2		4	8	
54																		0	10	
55		2		1					3									6	7	
56		1																1	148	143.67
57						46					6	22		67				141	142	

58																		0	141	
59																		0	2	
60						1									1			2	3	
61												1						1	5	
62						1					1							2	4	
63											1							1	16	
64						1								12				13	14	
65																		0	13	
66																		0	2	
67						1					1							2	2	
68																		0	11	
69		1				3					3				1	1		9	9	
70																		0	9	
71																		0	1	
72															1			1	3	
73		1				1												2	13	
74						6						1	3					10	14	
75						2												2	16	
76						3					1							4	6	
77																		0	4	
78																		0	10	
79						9					1							10	10	
80																		0	11	
81						1												1	4	
82											2	1						3	5	
83						1												1	11	
84						7												7	10	
85						2												2	9	
86																		0	7	
87						3					2							5	5	

88																		0	22	
89						17												17	17	
90																		0	65	
91						48												48	49	
92						1												1	49	
93																		0	15	
94						13											1	14	14	
95																		0	14	
96																		0	1	
97											1							1	2	
98						1												1	2	
99																		0	8	
100		2				4									1			7	8	
101											1							1	8	
102																		0	172	172.00
103		1				125					3			42				171	171	
104																		0	173	
105															1	1		2	2	
106																		0	2	
107																		0	0	
108																		0	0	
109																		0	1	
110		1																1	7	
111		5				1												6	7	
112																		0	8	
113		1							1									2	2	
114																		0	2	
115																		0	1	
116		1																1	3	
117															2			2	3	

118																		0	2	
119																		0	0	
120																		0	0	
121																		0	0	
122																		0	0	
123																		0	0	
124																		0	1	
125											1							1	1	
126																		0	1	
127																		0	0	
128																		0	0	
129																		0	0	
130																		0	1	
131																1		1	2	
132						1												1	2	
133																		0	5	
134																4		4	4	
135																		0	6	
136		2																2	16	
137						1										13		14	57	
138						40							1					41	57	
139						2												2	70	
140						27												27	29	
141																		0	30	
142												3						3	60	
143						47						8					2	57	60	
144																		0	58	
145						1												1	1	
146																		0	43	
147						42												42	43	

148						1												1	43	
149																		0	1	
150																		0	1	
151						1												1	84	
152						81					1			1				83	84	
153																		0	84	
154		1																1	20	
155						18						1						19	20	
156																		0	28	
157						6						3						9	11	
158						2												2	20	
159						6						3						9	13	
160		1										1				0		2	15	
161			1						2							1		4	6	
162																		0	4	
163																		0	2	
164		1				1												2	2	
165																		0	31	70.30
166				9		1						19						29	71	
167						1								41				42	74	
168						1								2				3	78	
169						25						8						33	37	
170														1				1	56	
171						22												22	71	
172						16								32				48	125	
173						53								2				55	104	
174														1				1	56	
175																		0	11	
176			1											9				10	38	179.25
177														28				28	126	

178														88				88	287	
179		1				1								169				171	288	
180						13						1		14		1		29	274	
181														74				74	181	
182						1								75		2		78	156	
183						1								3				4	84	
184				0										2				2	28	
185						21								1				22	89	97.63
186														65				65	95	
187														8				8	75	
188												1		1				2	130	
189						81				2	1	7		26		3		120	122	
190																		0	169	
191						1								48				49	49	
192																		0	52	
193														3				3	6	
194														3				3	6	
195																		0	34	
196						1								28	2			31	31	
197																		0	32	
198														1				1	3	
199												1		1				2	3	
200																		0	18	
201														16				16	45	83.29
202														17		12		29	99	
203														53		1		54	98	
204														14		1		15	71	
205														2				2	58	
206				2		2								37				41	91	
207		1				4								40		3		48	106	

208												1		4		12		17	67	
209														2				2	38	
210		1												18				19	58	
211			1											36				37	114	
212						3						1		54				58	133	
213														38				38	103	
214														7				7	50	
215						3								2				5	100	
216						1								87				88	95	
217														2				2	90	
218																		0	2	
219																		0	1	
220														1				1	1	
221																		0	1	
222																		0	1	
223												1						1	2	
224						1												1	7	
225						1								4				5	15	
226						1								8				9	15	
227						1												1	10	
228																		0	22	
229						1						2		17		1		21	22	
230		1																1	22	
231																		0	1	
232																		0	0	
233																		0	2	
234						1					1							2	5	
235											2	1						3	15	
236												3		7				10	18	
237														5				5	43	150.42

238						20								8				28	45	
239						7								5				12	62	
240		1												21				22	213	
241												4		173		2		179	230	
242		1		1		2								25				29	376	
243						1								167		0		168	244	
244			0			1								46				47	256	
245		1				2						1		35	1	1		41	93	
246		2				3												5	103	
247								4						50	3			57	69	
248											1	3		3				7	71	
249						1					2			2		2		7	15	
250						1												1	9	
251												1						1	5	
252						1					1	1						3	5	
253											1							1	4	
254																		0	7172	7172.67
255		12	8	19		375		91	1	3	215	116		6308		21	2	7171	7172	
256															1			1	7174	
257											1	1						2	5	
258						2												2	5	
259									1									1	3	
260																		0	7	
261		1				2					1				2			6	8	
262						1					1							2	9	
263		1																1	3	
264																		0	1	
265																		0	0	
266																		0	0	
267																		0	0	

268																		0	8	
269						4						4						8	9	
270											1							1	9	
271																		0	2	
272											1							1	1	
273																		0	3	
274											1	1						2	4	
275											1	1						2	4	
276																		0	13	
277		6				2								1	2			11	14	
278						2					1							3	22	
279												7			1			8	13	
280						2												2	10	
281																		0	3	
282															1			1	2	
283						1												1	5	
284		2														1		3	4	
285																		0	3	
286																		0	2	
287		1													1			2	2	
288																		0	2	
289																		0	1	
290															1			1	1	
291																		0	4	
292						3												3	3	
293																		0	4	
294						1												1	2	
295						1												1	7	
296						5												5	6	
297																		0	7	

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300																		0	0	
301																		0	2	
302											2							2	2	
303																		0	3	
304									1									1	1	
305																		0	2	
306											1							1	6	
307						3					2							5	10	
308				1								2			1			4	39	
309		1				29												30	34	
310																		0	45	
311						7					1	1			6			15	15	
312																		0	16	
313															1			1	7	
314						3						2			1			6	7	
315																		0	18	
316				1		6						5						12	23	
317						3						8						11	32	
318												8			1			9	28	
319						2						4			2			8	37	
320						13										7		20	36	
321				1		4						2			1			8	37	
322				1	1							4		1	2			9	25	
323						2						5			1			8	23	
324				2	1	1						2						6	20	
325						1						4			1			6	16	
326						2									2			4	23	
327						1						7			5			13	23	

328				1								4			1			6	20	
329															1			1	12	
330						3						1			1			5	21	
331				1		4						5	1		4			15	27	
332						3						1			3			7	25	
333				2											1			3	15	
334				2		2								1				5	10	
335				1		1												2	21	
336		1		1	1	11												14	21	
337						3						1				1		5	21	
338						1					1							2	7	
339																		0	6	
340				2		1						1						4	63	115.46
341				1		52									4	2		59	67	
342						3						1						4	75	
343				1		9			1							1		12	38	
344				2		4			2							14		22	54	
345				4	4	11					1							20	48	
346						5									1			6	58	
347				1		30						1						32	60	
348						21									1			22	77	
349						22						1						23	102	
350				1		54						1			1			57	313	
351				4		228									1			233	324	
352				31		2									1			34	290	
353				1		21					1							23	162	
354				1		102						1				1		105	240	
355				2		109									1			112	243	
356			1			17									2	6		26	186	
357		1				46										1		48	86	

358						11									1			12	75	
359		1				12						2						15	92	
360		4		6		37						4		1	11	2		65	105	
361						25												25	258	
362						167										1		168	217	
363				2		20									2			24	227	
364						33						1			1			35	63	
365						3								1				4	63	
366						10			3						4	7		24	34	
367				4		1										1		6	38	
368						6						1			1			8	39	
369				1		13			2			4			1	4		25	69	
370				1		34										1		36	64	
371						3												3	58	
372				2		17												19	39	
373						17												17	47	
374						9						1				1		11	33	
375						2			1		1				1			5	34	
376						16						1			1			18	164	
377						138									3			141	163	
378		1				2									1			4	208	
379						63												63	78	
380				1		6									2	2		11	80	
381						1			2			3						6	23	
382						6												6	31	226.76
383						16			1							2		19	55	
384						22						1	1		1	5		30	167	
385						109			1	1		3			1	3		118	186	
386		4		2	2	19						5			5	1		38	200	
387						40						3				1		44	184	

388						101						1						102	441	
389		2	2	13		212	2		1		8	41		2	6	6		295	407	
390		1				6			1		1				1			10	321	
391						12			3						1			16	90	
392						63			1									64	165	
393		7				65			6			2			4	1		85	258	
394		1				102			4		1	1						109	245	
395				1		45			2						2	1		51	229	
396						63			5							1		69	341	
397				1		220												221	298	
398						8												8	237	
399						3				1						4		8	19	
400						1			2									3	11	
401																		0	4	
402						1												1	1	
403																		0	5	
404						3			1									4	6	
405														2				2	7	
406						1												1	9	
407				1		5												6	7	
408																		0	9	
409						3												3	3	
410																		0	3	
411																		0	0	
412																		0	91	
413						91												91	92	
414															1			1	94	
415														2				2	4	
416														1				1	3	
417																		0	27	

418														26				26	26	
419																		0	579	388.20
420				14		301	1					124		109	2	2		553	575	
421				4										18				22	633	
422						6								48		4		58	88	
423														8				8	66	
424																		0	11	
425				2		1												3	13	
426									3					7				10	33	196.40
427		2		7		3			4							4		20	38	
428		1							7									8	34	
429				3					3									6	297	
430		2	1	40		22	1		63	2	2	142	1	3		4		283	289	
431																		0	291	
432						8												8	8	
433																		0	11	
434		1				2												3	22	
435						17								1		1		19	93	397.27
436						70								1				71	94	
437				1		1								1		1		4	148	
438		1		2		70												73	81	
439												3		1				4	206	
440		1				115								8		5		129	239	
441						104			2									106	245	
442						1								9				10	145	
443						12			1			1		14		1		29	45	
444				1										4		1		6	62	
445														26		1		27	67	
446						30						1		3				34	95	
447		1		2		14			3			4		8		2		34	152	

448		1		4		59			3			1		14		2		84	120	
449				1								1						2	114	
450						3								25				28	57	
451				3										24				27	218	
452						7								155		1		163	299	
453		2		6		8						5		87		1		109	428	
454		1				59						1		92		3		156	309	
455		1		1		2						3		28		9		44	551	
456		1		8		106						6		230				351	644	
457				3		68						1		177				249	1014	
458		6		5		72						11	2	313	2	3		414	1036	
459				4	1	100			1		1	2		260	3	1		373	906	
460				1		114						2		2				119	611	
461		1		6		93						5		14				119	338	
462				2		59						3		36				100	309	
463						84								4		2		90	477	
464		1				281						1				4		287	554	
465		1		1		164								10		1		177	572	
466		1				60						1		46				108	460	
467		1		4		167										3		175	343	
468		1				53						4		2				60	263	
469						24						2				2		28	220	
470						132												132	166	
471				4								1				1		6	187	
472						48									1			49	146	
473						83						6				2		91	232	
474						90						2						92	184	
475						1												1	3921	
476		5		9		932					4	127	1	2749	1			3828	4311	
477			1	13		427						10		31				482	4517	

478		3		4		183						14				3		207	799	
479		1		3		88						18						110	501	
480		12		5		162						5						184	339	
481		1		1		33						10						45	355	
482		1				120			1			4						126	223	
483		2				49						1						52	282	
484		13		2	1	72						13	1			2		104	205	
485		4		2		26						16			1			49	304	
486		3		8		122						18						151	286	
487		1				61						24						86	270	
488		2		3		11					1	13		1		2		33	159	
489		1				25						14						40	133	
490		8	1	4	4	20						22			1			60	201	
491	1	18	1	6	3	32					1	39						101	227	
492		2				55						9						66	225	
493		5		4		39						9			1			58	131	
494		2		2		1						2						7	71	
495												6						6	77	
496	1	12		2		23					1	25						64	234	
497	16	60		3	1	74						9				1		164	242	
498		1										13						14	330	
499	1	12		7	1	118			1			9	1			2		152	180	
500		1				1						12						14	238	
501		5		3	11	23						28				2		72	150	
502		5		1		48						10						64	312	
503		8		2		139						27						176	305	
504		4		4		43						14						65	258	
505		3				5						8				1		17	115	
506		6				13						14						33	57	
507		1		2								4						7	76	

508		7		2		2						25						36	72	
509		1			4	10						14						29	88	
510				1		12						10						23	118	
511		4		2		50						7				3		66	139	
512		1		1		31						17						50	178	
513		10	1	1		26						20			3	1		62	152	
514		3				35						2						40	130	
515		2				23						3						28	113	
516	7	13				18						5	2					45	108	
517		5	2	2		22			2		1	1						35	94	
518		2				11										1		14	72	
519		14				9												23	40	
520		2				1												3	26	
521																		0	16	
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523		1													1			2	19	
524		1				2						1						4	7	
525											1							1	6	
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527		1																1	10	
528		2				6												8	18	
529		1				8												9	40	
530		9			2	7					1	3			1			23	32	
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532																		0	3	
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535		1																1	5	
536																		0	2	
537		1																1	2	

538						1												1	5	
539						2									1			3	4	
540																		0	9	
541		3				1						1			1			6	6	
542																		0	16	
543		3				2										5		10	33	
544						22					1							23	36	
545						2			1									3	26	
546																		0	3	
547																		0	1	
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549		2				1						1			2			6	7	
550																		0	6	
551																		0	0	
552																		0	0	
553																		0	1	
554		1																1	1	
555																		0	4	
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557				1														1	5	
558						1												1	2	
559																		0	2	
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562																1		1	2	
563											1							1	2	
564																		0	4	
565						1						1			1			3	5	
566																2		2	7	
567											1				1			2	4	

568																		0	3	
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570												1						1	2	
571																		0	1	
572																		0	1	
573												1						1	2	
574						1												1	4	
575									2									2	4	
576												1						1	7	
577						3						1						4	7	
578						2												2	6	
579																		0	3	
580											1							1	1	
581																		0	1	
582																		0	0	
583																		0	2	
584						2												2	11	
585				1							0	1				7		9	13	
586												2						2	11	
587																		0	5	
588						3												3	4	
589											1							1	4	
590																		0	3	
591												1				1		2	2	
592																		0	2	
593																		0	0	
594																		0	0	
595																		0	1	
596											1							1	2	
597									1									1	3	

598						1												1	4	
599						2												2	3	
600																		0	4	
601				2														2	5	
602		3																3	24	
603		4				5			4							6		19	25	
604						1			2									3	22	
605																		0	3	
606																		0	1	
607						1												1	2	
608		1																1	3	
609						1												1	3	
610		1																1	2	
611																		0	4	
612						1						2						3	4	
613		1																1	5	
614				1														1	5	
615		1				2												3	4	
616																		0	3	
617																		0	0	
618																		0	0	
619																		0	1	
620											1							1	2	
621		1																1	3	
622										1								1	3	
623									1									1	13	
624		2				6			1		1				1			11	22	
625		1		1		2			1		4					1		10	21	
626																		0	18	
627		2				1			1		2					2		8	15	

628						4					2					1		7	23	
629		3		3											1	1		8	23	
630										2	6							8	18	
631				1								1						2	18	
632		4									4							8	21	
633		1							1		5			2		2		11	22	
634											1		1			1		3	18	
635																4		4	7	
636																		0	8	
637											4							4	6	
638						2												2	7	
639											1							1	5	
640						1					1							2	6	
641											3							3	5	
642																		0	9	
643		2		1		1									1	1		6	11	
644						4			1									5	13	
645											2							2	12	
646											5							5	7	
647																		0	9	
648											4							4	8	
649						1					3							4	11	
650											3							3	12	
651						2					3							5	14	
652											6							6	17	
653											5					1		6	21	
654		4				1					3					1		9	15	
655																		0	9	
656																		0	0	
657																		0	5	

658											4	1						5	19	
659		1				2				1	10							14	22	
660											3							3	18	
661		1																1	7	
662		1									2							3	4	
663																		0	12	
664		1				1			1	1	3	1					1	9	13	
665						1					3							4	14	
666											1							1	19	
667		1				6				1	4					2		14	21	
668		1				3										2		6	32	
669						1										11		12	21	
670		1				1					1							3	19	
671		2				1			1									4	13	
672						1					4				1			6	13	
673										1	2							3	10	
674											1							1	20	
675						6			1	1	7				1			16	23	
676											1					5		6	26	
677											4							4	16	
678		1									5							6	23	
679						3					1					9		13	36	
680				1		4			1		8	1				1	1	17	35	
681											2				3			5	24	
682											2							2	8	
683				1														1	9	
684											4				2			6	11	
685				2							2							4	17	
686						5					2							7	19	
687				1							7							8	22	

688						1					6							7	22	
689						2					5							7	48	
690						15			1		17				1			34	44	
691									1		2							3	45	
692											8							8	12	
693				1														1	12	
694												1			2			3	19	
695											14					1		15	30	
696									1		10					1		12	41	
697				3		1					9					1		14	39	
698		3		3		1					5					1		13	35	
699						2					2					4		8	33	
700		3									8				1			12	24	
701											4							4	24	
702						3					4	1						8	14	
703											2							2	13	
704									1		2							3	13	
705		1				5					2							8	14	
706				1					1		1							3	14	
707											3							3	30	
708		1				11			5		6				1			24	43	
709						5			1		9				1			16	54	
710						6									1	7		14	39	
711						3				2	3					1		9	27	
712						4												4	15	
713											2							2	8	
714									1			1						2	13	
715		3				3					2					1		9	51	
716		6	1			27				2						4		40	51	
717	1					1												2	59	

718				1		12			4									17	27	
719											7					1		8	59	142.75
720						5					2		1			26		34	116	
721		6		5		33			3	1	3	9				14		74	126	
722		1				15				1	1							18	134	
723		2				21			6	1	6					6		42	88	
724		6		1		7			1		2				4	7		28	96	
725		6		2		4					4	3			3	4		26	198	
726		21		7		77			3	1	8	4			3	19	1	144	175	
727		2								0	2						1	5	150	
728						0				1								1	9	
729											2				1			3	4	
730																		0	16	
731						8			1	1	2					1		13	15	
732									1							1		2	24	
733						9												9	11	
734																		0	10	
735											1							1	53	
736		2		1		24			1		14	4				6		52	53	
737																		0	53	
738											1							1	4	
739	1					2												3	4	
740																		0	20	
741		1				1				1	12					2		17	19	
742											2							2	19	
743																		0	2	
744																		0	6	
745						2				1	2				1			6	6	
746																		0	6	
747																		0	0	

748																		0	0	
749																		0	3	
750											3							3	10	
751		1									4				2			7	10	
752																		0	7	
753																		0	3	
754											3							3	7	
755		2		1								1						4	7	
756																		0	4	
757																		0	0	
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759		1																1	1	
760																		0	1	
761																		0	0	
762																		0	0	
763																0		0	1	
764											1							1	2	
765											1							1	2	
766																		0	1	
767																		0	0	
768																		0	1	
769																1		1	2	
770		1																1	2	
771																		0	6	
772											4				1			5	5	
773																		0	5	
774																		0	0	
775																		0	0	
Grand Total	29	535	34	413	37	10449	4	102	195	31	681	1417	16	15660	181	426	9			

20. APPENDIX H: THE TARGET SPECIES FOR SAFE CROSSING OPPORTUNITIES IN THE MITIGATION ZONES FOR HWY 16 AND THE RAILROAD THROUGH JNP AND MRPP

Mitigation zone (100 m units)	Species, number of observations and percentage of observations			Focal species (excluding bobcat, red fox and coyote)	Focal species and selected other species (>10%)	Recommendation (for the largest structures in a mitigation zone)
Hwy 16 through JNP						
1-21	SHEE	706	68.02	black bear, wolf, cougar, grizzly bear, Canada lynx	bighorn sheep, elk	1 large overspan bridge or large mammal underpass
	ELK	149	14.35			
	MULE	72	6.94			
	WHIT	40	3.85			
	MOOS	26	2.50			
	BLAC	19	1.83			
	COYO	12	1.16			
	WOLF	4	0.39			
	COUG	3	0.29			
	GRIZ	3	0.29			
	LYNX	3	0.29			
	DEER	1	0.10			
27-99	ELK	714	50.93	black bear, wolf, grizzly bear, cougar	elk, white-tailed deer, bighorn sheep	3 large overspan bridges or large mammal underpasses
	WHIT	156	11.13			
	SHEE	144	10.27			
	MULE	136	9.70			
	BLAC	102	7.28			
	MOOS	68	4.85			
	WOLF	31	2.21			
	COYO	28	2.00			
	GRIZ	8	0.57			
	DEER	7	0.50			
	GOAT	5	0.36			
	COUG	3	0.21			
116-154	SHEE	3131	65.11	wolf, black bear, cougar, grizzly bear, Canada lynx, wolverine	bighorn sheep, elk	2 large overspan bridges or large mammal underpasses
	ELK	1232	25.62			
	GOAT	287	5.97			
	MULE	56	1.16			
	WHIT	32	0.67			
	COYO	23	0.48			

	WOLF	14	0.29			
	BLAC	12	0.25			
	MOOS	8	0.17			
	COUG	5	0.10			
	GRIZ	3	0.06			
	FOX	2	0.04			
	DEER	1	0.02			
	LYNX	1	0.02			
	REFO	1	0.02			
	WOLV	1	0.02			
228-319	SHEE	6338	78.43	wolf, black bear, grizzly bear, Canada lynx, cougar, wolverine	bighorn sheep, elk	4 large overspan bridges or large mammal underpasses
	ELK	1232	15.25			
	MOOS	124	1.53			
	MULE	120	1.48			
	COYO	89	1.10			
	WHIT	56	0.69			
	WOLF	47	0.58			
	GOAT	32	0.40			
	BLAC	14	0.17			
	GRIZ	7	0.09			
	DEER	6	0.07			
	LYNX	6	0.07			
	COUG	4	0.05			
	REFO	4	0.05			
	FOX	1	0.01			
	WOLV	1	0.01			
335-377	ELK	1564	85.70	wolf, grizzly bear, black bear, cougar	elk	2 large overspan bridges or large mammal underpasses
	COYO	76	4.16			
	WOLF	57	3.12			
	WHIT	43	2.36			
	MULE	33	1.81			
	SHEE	25	1.37			
	GRIZ	8	0.44			
	BLAC	7	0.38			
	DEER	5	0.27			
	MOOS	5	0.27			
	COUG	1	0.05			
	REFO	1	0.05			
380-512	ELK	10039	61.04	wolf, black bear, grizzly bear, cougar, Canada lynx	elk, bighorn sheep	1 or 2 wildlife overpasses and 5 or 6 large overspan bridges or large mammal underpasses
	SHEE	4001	24.33			
	MULE	1478	8.99			
	COYO	297	1.81			
	WOLF	184	1.12			

	BLAC	171	1.04			
	GRIZ	164	1.00			
	WHIT	55	0.33			
	MOOS	24	0.15			
	COUG	9	0.05			
	REFO	9	0.05			
	DEER	7	0.04			
	BEAR	4	0.02			
	FOX	2	0.01			
	LYNX	2	0.01			
535-604	ELK	522	55.65	wolf, black bear, grizzly bear, cougar, Canada lynx	elk, moose	4 large overspan bridges or large mammal underpasses
	MOOS	163	17.38			
	WHIT	85	9.06			
	WOLF	58	6.18			
	BLAC	41	4.37			
	MULE	27	2.88			
	COYO	25	2.67			
	GRIZ	6	0.64			
	COUG	4	0.43			
	BEAR	2	0.21			
	LYNX	2	0.21			
	REFO	2	0.21			
	DEER	1	0.11			
624-729	MOOS	243	36.76	wolf, black bear, grizzly bear, Canada lynx, caribou, wolverine, cougar	moose, elk	1 wildlife overpass and 4 large overspan bridges or large mammal underpasses
	ELK	189	28.59			
	WOLF	65	9.83			
	BLAC	53	8.02			
	COYO	29	4.39			
	GRIZ	25	3.78			
	WHIT	21	3.18			
	MULE	16	2.42			
	LYNX	10	1.51			
	CARI	4	0.61			
	SHEE	2	0.30			
	WOLV	2	0.30			
	COUG	1	0.15			
	REFO	1	0.15			
733-756	ELK	211	44.51	wolf, black bear, grizzly bear, Canada lynx, wolverine	elk, wolf, moose	1 large overspan bridge or large mammal underpass
	WOLF	86	18.14			
	MOOS	61	12.87			
	BLAC	45	9.49			
	MULE	17	3.59			
	COYO	16	3.38			

	GRIZ	16	3.38			
	WHIT	11	2.32			
	LYNX	7	1.48			
	WOLV	2	0.42			
	BEAR	1	0.21			
	REFO	1	0.21			
Hwy 16 through MRPP						
16-38	WOLF	2	100.00	wolf	wolf	1 large overspan bridge or large mammal underpass
192-214	BEAR	2	100.00	bear	bear	1 large overspan bridge or large mammal underpass
371-394	BEAR	3	100.00	bear	bear	1 large overspan bridge or large mammal underpass
602-625	BEAR	2	100.00	bear	bear	1 large overspan bridge or large mammal underpass
Railroad through JNP						
1-14	SHEE	1875	96.45	black bear, cougar, wolf, Canada lynx	bighorn sheep	1 large overspan bridge or large mammal underpass
	ELK	17	0.87			
	BLAC	12	0.62			
	COYO	8	0.41			
	MOOS	8	0.41			
	GOAT	7	0.36			
	COUG	6	0.31			
	MULE	5	0.26			
	WOLF	3	0.15			
	LYNX	2	0.10			
	WHIT	1	0.05			
89-127	ELK	210	76.09	black bear, grizzly bear, wolf, wolverine	elk, bighorn sheep	2 large overspan bridges or large mammal underpasses
	SHEE	42	15.22			
	BLAC	11	3.99			
	MOOS	6	2.17			
	WHIT	4	1.45			
	GRIZ	1	0.36			
	WOLF	1	0.36			
	WOLV	1	0.36			
149-215	SHEE	1067	69.11	wolf, black bear, cougar, grizzly bear, Canada lynx	bighorn sheep, elk	3 large overpan bridges or large mammal underpasses
	ELK	366	23.70			
	MULE	47	3.04			
	WOLF	36	2.33			
	COYO	11	0.71			

	BLAC	6	0.39			
	COUG	3	0.19			
	GRIZ	2	0.13			
	LYNX	2	0.13			
	MOOS	2	0.13			
	WHIT	2	0.13			
234-288	SHEE	6856	87.24	black bear, wolf, cougar, Canada lynx, grizzly bear, wolverine	bighorn sheep	3 large overspan bridges or large mammal underpasses
	ELK	431	5.48			
	MOOS	231	2.94			
	MULE	144	1.83			
	GOAT	95	1.21			
	BLAC	28	0.36			
	WOLF	27	0.34			
	COYO	20	0.25			
	WHIT	12	0.15			
	COUG	8	0.10			
	LYNX	3	0.04			
	GRIZ	2	0.03			
	WOLV	2	0.03			
364-394	ELK	1147	83.60	wolf, grizzly bear, black bear, cougar, Canada lynx	elk	1 wildlife overpasses and 1 large overspan bridge or large mammal underpass
	MULE	68	4.96			
	WOLF	35	2.55			
	WHIT	34	2.48			
	GRIZ	26	1.90			
	COYO	24	1.75			
	BLAC	16	1.17			
	MOOS	11	0.80			
	SHEE	3	0.22			
	COUG	2	0.15			
	DEER	2	0.15			
	FOX	2	0.15			
	LYNX	1	0.07			
	REFO	1	0.07			
454-477	SHEE	3994	53.03	wolf, black bear, cougar, grizzly bear	bighorn sheep, elk	1 large overspan bridge or large mammal underpass
	ELK	3219	42.74			
	MULE	188	2.50			
	COYO	61	0.81			
	WOLF	31	0.41			
	BLAC	20	0.27			
	WHIT	7	0.09			
	MOOS	5	0.07			
	REFO	3	0.04			
	COUG	1	0.01			

	DEER	1	0.01			
	GRIZ	1	0.01			
486-541	ELK	1136	57.23	black bear, wolf, cougar, grizzly bear	elk, mule deer, black bear	3 large overspan bridges or large mammal underpasses
	MULE	442	22.27			
	BLAC	248	12.49			
	COYO	61	3.07			
	BEAR	26	1.31			
	DEER	26	1.31			
	WOLF	14	0.71			
	WHIT	11	0.55			
	COUG	8	0.40			
	MOOS	6	0.30			
	GRIZ	3	0.15			
	REFO	3	0.15			
	SHEE	1	0.05			
597-621	ELK	14	31.11	black bear, grizzly bear, wolf	elk, black bear, grizzly bear, wolf	2 large overspan bridges or large mammal underpasses
	BLAC	12	26.67			
	GRIZ	7	15.56			
	WOLF	6	13.33			
	COYO	3	6.67			
	MULE	2	4.44			
	MOOS	1	2.22			
643-678	MOOS	89	50.57	wolf, black bear, Canada lynx, grizzly bear, wolverine	moose, elk, wolf	2 large overspan bridges or large mammal underpasses
	ELK	32	18.18			
	WOLF	23	13.07			
	BLAC	16	9.09			
	LYNX	5	2.84			
	GRIZ	4	2.27			
	WHIT	3	1.70			
	MULE	2	1.14			
	COYO	1	0.57			
	WOLV	1	0.57			
707-732	ELK	242	44.81	wolf, black bear, grizzly bear, Canada lynx, wolverine, cougar	elk, wolf, moose, black bear	1 wildlife overpass and 1 large overspan bridge or large mammal underpass
	WOLF	92	17.04			
	MOOS	64	11.85			
	BLAC	54	10.00			
	GRIZ	26	4.81			
	MULE	17	3.15			
	COYO	16	2.96			
	WHIT	14	2.59			
	LYNX	10	1.85			
	WOLV	2	0.37			
	BEAR	1	0.19			

	COUG	1	0.19			
	REFO	1	0.19			
Railroad through MRPP						
Albreda 43-65	BLACK BEAR	1	100.00	black bear	black bear	1 large overspan bridge or large mammal underpass
Albreda 118-140	BLACK BEAR	1	100	black bear	black bear	1 large overspan bridge or large mammal underpass
Albreda 504-527	WOLF	1	100	wolf	wolf	1 large overspan bridge or large mammal underpasses
Robson 77-99	WOLF	1	100	wolf	wolf	1 large overspan bridge or large mammal underpass

21. APPENDIX I: HOME RANGE ESTIMATES

Home range size and diameter estimates for the focal species and selected other species. 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)
Focal species		
Fisher (*Martes pennanti*)	47,700 ha 24,644 m	47,700 ha for females for females, 219,000 ha for males (Weir & Corbould, 2010)
Wolverine (*Gulo gulo)*	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)
Canada lynx (*Lynx canadensis)*	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 (*Puma concolor)*	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)
Red fox (*Vulpes vulpes*)	1,500 ha 4,371 m	1,611 ha (range 277-3,420 ha) (Jones & Theberge, 1982), 350 ha (Frey & Conover, 2006)
Coyote (*Canis latrans)*	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 (*Canis lupus*)	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 (*Ursus americanus)*	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 (*Ursus arctos*)	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)
Caribou (*Rangifer tarandus caribou*)	40,000 ha 12,739 m	38,500 ha (range 12,800-73,700 ha) (Mercer et al., 2004), 30,000-150,000 ha (Dalerum et al., 2007)
Selected other species		
White-tailed deer (*Odocoileus virginianus)*	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 (*Odocoileus hemionus)*	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 (*Cervus canadensis*)	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 (*Alces alces)*	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 (*Oreamnos americanus*)	300 ha 1,955 m	280 ha for adult males, 480 ha for adult females (Singer & Doherty, 1985)
Bighorn sheep (*Ovis canadensis*)	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)

22. APPENDIX J: QUICK ASSESSMENT OF THE POTENTIAL IMPACT OF ROAD AND RAILROAD MORTALITY ON POPULATION PERSISTENCE OF THE FOCAL SPECIES IN JNP AND MRPP

1.1 Introduction

Low population viability for a wildlife species in an area is typically caused by small and isolated populations that have limited ability to cope with or recover from a "disaster" or a "combination of disasters". There may simply be too few remaining individuals in a (sub)population and re-colonization by individuals from elsewhere may be unlikely because of the presence of barriers in the landscape and the great distance to other (sub)populations. As populations become smaller and more isolated, more events qualify as a "disaster" or "combination of disasters". For example, diseases and habitat alteration or destruction can take place across relatively large areas and may expose the entire local population to higher mortality risks. However, when the local population size is very low already, the accidental death of just a few individuals, especially reproducing females, may also qualify as a disaster as the local population may not be able to recover from such demographic stochasticity (e.g. Hebblewhite et al., 2009).

Depending on the species and the local or regional context, direct wildlife mortality through collisions with vehicles and trains may be a disaster or a series of disasters for the (sub)population of a species in that area. The level of the impact on the persistence of the species concerned depends on each species' ability to offset this unnatural mortality through having a relatively high population size to begin with, through birth and through potential immigration from neighboring areas.

The objective of this quick-scan is to explore whether population persistence of the focal species in Jasper National Park (JNP) and Mount Robson Provincial Park (MRPP) may be affected by road and railroad mortality within these parks. Given the available budget the researchers chose a relatively simple step-by-step approach that allowed for the identification of functional habitat networks and an evaluation of the persistence of the network population for each focal species.

The population persistence assessment was conducted for the two protected areas (JNP and MRPP) combined and ignored the potential presence of populations in adjacent areas outside the two parks. The researchers consider this justified as land and wildlife management is likely to be different in the areas outside the two parks which may result in (much) lower population densities and at least a certain degree of isolation from the populations in the two parks. Most importantly, the two parks have no jurisdiction in the unprotected areas. Thus one could argue that it is up to the management of the two parks to see if the two parks can have wildlife populations persist under different management strategies in the two parks, or whether the areas of the two parks (and therefore the wildlife populations) are simply too small to have populations persist independent from the presence of populations in the neighboring areas that may be unprotected. Two possible management strategies for the two parks are: 1. No road or railroad mitigation measures for the selected species and 2. Implementation of mitigation measures aimed at reducing direct road and railroad mortality and providing safe crossing opportunities for wildlife.

1.2 Methods

The researchers used a simple step-by-step approach. For each focal species the population density in each of the habitat types present in JNP and MRPP was estimated based on the literature. The resulting population sizes were then compared to a set of standards for population persistence. The approach is based on the Key Patch approach developed by Verboom et al. (2001), in combination with the Ecologically Scaled Landscape Indices (ESLIs) approach developed by Vos et al. (2001) and the Landscape Cohesion approach developed by Opdam et al. (2003). In order to explore the full range of potential outcomes the researchers developed scenarios in which parameter settings varied between "worst-case" and "best-case" situations.

1.2.1: Step 1: Species selection

The researchers conducted the population persistence analyses for all focal species (see section 2.4; Table 1), except red fox (*Vulpes vulpes*). Red fox was excluded from the analyses as this species is not considered a conservation concern in the area. The red fox occurs as an incidental in the region and this species appears to expand in numbers and area with human disturbance, including transportation infrastructure and land use (Personal communication Terry Antoniuk, Salmo Consulting Inc., Calgary, Alberta, Canada).

1.2.2: Step 2: Defining scenarios for population structure

For most of the focal species no data have been collected on the barrier effect of the transportation corridors that cross the study area. Hence it is unknown to what extent the population is structured into subpopulations due to habitat fragmentation by the highways and the railroad that cross the parks. Therefore in a second step the researchers defined three scenarios for the population structure in the study area for each focal species:

- *Scenario 1:* All individuals that occur within JNP and MRPP are part of the same population. In this scenario neither Hwy 16 (including the adjacent railroad) nor Hwy 93 are considered a barrier.
- *Scenario 2:* There are two subpopulations within JNP and MRPP; one north of Highway 16 (subareas 1 and 4; Figure 1) and one south of Highway 16 (subareas 2, 3 and 5). In this scenario Hwy 16 is considered to be a partial but not an absolute barrier, while Hwy 93 is not considered a barrier at all. The two subpopulations form one network population (a 'meta-population') with Hwy 16 as a partial barrier to the movements of the individuals.
- *Scenario 3:* There are three subpopulations within JNP and MRPP; one north of Hwy 16 (subareas 1 and 4), one south of Hwy 16 and east of Hwy 93 (subarea 2), and one south of Hwy 16 and west of Hwy 93 (subareas 3 and 5). In this scenario both Hwy 16 and Hwy 93 are considered to be a partial but not an absolute barrier. The three subpopulations form one network population (a 'meta-population'), with both Hwy 16 and Hwy 93 as a partial barrier to the movements of the individuals.

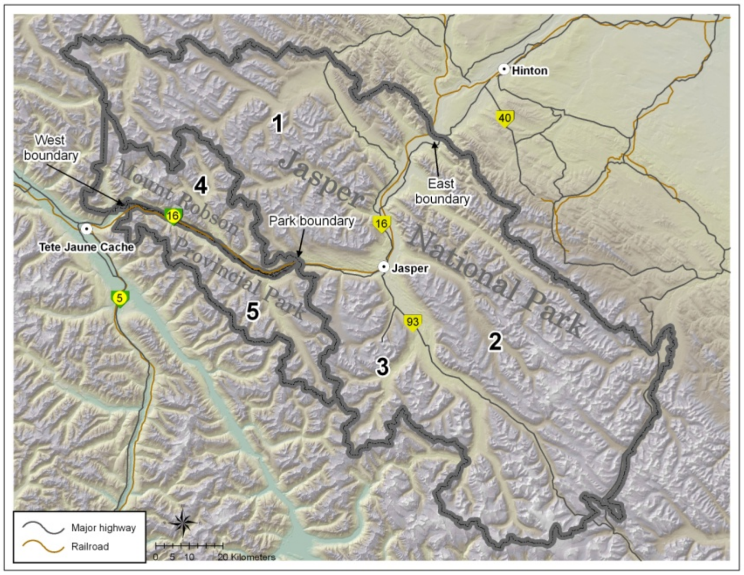

Figure 1: Division of the study area in subareas: 1: JNP north of Hwy 16, 2: JNP south of Hwy 16 and east of Hwy 93, 3: JNP south of Hwy 16 and west of Hwy 93, 4: MRPP north of Hwy 16, 5: MRPP south of Hwy 16.

In order to simplify the analyses the researchers did not consider the area in between Hwy 16 and the railroad as a separate subarea. Instead Hwy 16 was considered the boundary between subareas 1 and 4 to the north and subareas 2, 3 and 5 to the south. Because the boundary between JNP and MRPP is an administrative boundary only, the researchers ignored this boundary in defining scenarios for population structure. Table 1 shows the surface area for the different subareas for each population structure scenario.

Table 1. Surface area of the (sub)populations for each scenario for the population structure.

Scenario population structure	**Area name (subareas)**	**Area (ha)**	**%**
Scenario 1	N and S of Hwy 16 (1, 2, 3, 4 and 5)	1,348,946	100.00
Scenario 2	N of Hwy 16 (1 and 4)	527,044	39.07
	S of Hwy 16 (2, 3 and 5)	821,902	60.93
Scenario 3	N of Hwy 16 (1 and 4)	527,044	39.07
	S Hwy 16, E Hwy 93 (2)	436,524	32.36
	S Hwy 16, W Hwy 93 (3 and 5)	385,378	28.57

1.2.3: Step 3: Population Size Estimates

The researchers estimated the population size for each (sub)population identified in the three population structure scenarios (see step 2 in the previous section). The researchers based the population size estimates on the literature and corrected the estimates for the presence and the surface area of the different habitat types that occur in JNP and MRPP. The researchers followed the following step-wise approach:

Step 3.1: The researchers conducted a literature review for population densities of the focal species in different areas and regions throughout North America (Table 2 and 3). However, the researchers placed an emphasis on studies from the Rocky Mountain ecosystem where possible as those population densities are most likely to be similar to those found in JNP and MRPP. The researchers calculated the average population density as well as the minimum and maximum population density based on the densities reported in the studies. In addition to the average, minimum and maximum densities reported in the literature the researchers also calculated the 'likely' densities for the focal species based on the studies conducted in the most similar habitat and in areas that were relatively nearby.

Step 3.2: The habitat types in which the different studies were conducted were translated to the habitat types present in the study area. The researchers used the Globcover 2009 (Global Land Cover Map) database (release 21 December 2010) to calculate the area (in ha) of the different habitat types present in the three subareas (ESA, 2010) (Table 4). This database is based on satellite images and classifies habitat across the globe with 300 m (984 ft) resolution. Similar habitat types were assigned 100% of the population density found in other studies whereas habitat types that were considered not similar and also marginal were only assigned 10% of those population densities and not similar and also unsuitable habitat was assigned 0%. This resulted in a habitat similarity and suitability index (Table 5).

Step 3.3: The researchers calculated the population size for each (sub)population identified in the three population structure scenarios (see step 2 in the previous section). The researchers calculated estimates for the average population size as well as the minimum and maximum population size based on the densities reported in the literature (see step 3.1). In addition to the average, minimum and maximum population size the researchers also calculated the 'likely' population size for the focal species based on the studies conducted in the most similar habitat and geographic proximity. For one species, caribou, the researchers also used actual population sizes in the three subareas (Parks Canada, 2011b) and conducted separate analyses with these numbers.

The population sizes (P) for each subpopulation were calculated as follows:

$$P_{minimum} = \sum(A_{habitat\ type\ i} * SI_{habitat\ type\ i}) * D_{minimum}$$

$$P_{average} = \sum(A_{habitat\ type\ i} * SI_{habitat\ type\ i}) * D_{average}$$

$$P_{maximum} = \sum(A_{habitat\ type\ i} * SI_{habitat\ type\ i}) * D_{maximum}$$

$$P_{likely} = \sum(A_{habitat\ type\ i} * SI_{habitat\ type\ i}) * D_{likely}$$

$$P_{actual} = \sum(A_{habitat\ type\ i} * SI_{habitat\ type\ i}) * D_{actual}$$

In which:

$A_{habitat\ type\ i}$ = surface area of habitat type i within the (sub)population (ha)

$SI_{habitat\ type\ i}$ = habitat similarity and suitability index for habitat type I (%)

$D_{minimum}$ = minimum population density, based on the literature (ha^{-1})

$D_{average}$ = average population density, based on the literature (ha^{-1})

$D_{maximum}$ = maximum population density, based on the literature (ha^{-1})

D_{likely} = likely population density, based on the literature (ha^{-1})

D_{actual} = actual population density, based on counts in the subareas (ha^{-1}); for caribou only

Table 2. Total population density (N/100 km2) estimates for the focal species (excluding red fox). The population density estimates are averages based on the literature. The density estimates relate to females and males combined across all age groups. The densities marked in yellow are considered most representative for JNP and MRPP based on habitat and geographic proximity.

Species	Density (N/100 km^2) (min-max)	Source(s)
Fisher (*Martes pennanti*)	14.9 (3.0-35.7) 3.5	3.0/100 km^2 (c.i. 1.8-4.6) in suitable habitat (O'Neil & Swanson, 2010); 3.5 (Heinemeyer & Jones, 1994); 5.0-35.7/100 km^2 (Arthur et al., 1989); 32.7/100 km^2 of suitable habitat (Koen et al., 2007)
Wolverine (*Gulo gulo)*	0.9 (0.1-1.5) 0.8	0.1-0.2/100 km^2 (Squires et al., 2007); 0.97/100 km^2 (Royle et al., 2011); 1.5/100 km^2 (Hornocker & Hash 1981)
Canada lynx (*Lynx canadensis)*	10.5 (2.0-44.9) 5.5	2.0; 2.8; 3.5; 3.6; 3.7; 5.2; 6.2; 7.6; 7.9; 8.5; 9.9/100 km2 (Stenseth et al., 1998); 2.0; 2.7; 4.3; 5.6; 10.6, 24.3; 44.5; 44.9/100 km^2 (Slough & Mowat, 1996); 9.2-13.0/100 km^2 (Vashon et al., 2008)
Cougar (*Puma concolor)*	2.6 (0.9-4.6) 2.6	0.9; 0.9; 1.1; 1.1; 1.2; 1.5/100 km^2 (Lambert et al., 2006); 3.0; 4.0; 4.0; 4.2; 4.6/100 km^2 (Ross & Jalkotzky, 1992); 3.5; 3.7/100 km^2 (Spreadbury et al., 1996)
Coyote (*Canis latrans*)	24.1 (7.0-71.0) 22.0	7.0; 12.0; 13.0; 14.0; 15.0; 19.0; 19.0; 20.0; 21.0; 22.0; 25.0; 26.0/100 km^2 (Pyrah, 1984); 7.8; 13.9; 15.6; 20.6; 25.0; 28.9; 34.4; 37.2; 42.2; 44.4/100 km^2 (Todd et al., 1981); 71.0 (min 49; max 116)/100 km^2 (Hein & Andelt, 1995)
Wolf (*Canis lupus*)	0.8 (0.2-1.8) 0.3	0.2; 0.3 (Hebblewhite et al., 2007); 0.4; 0.5; 0.8; 0.8; 1.1; 1.4/100 km^2 (Fuller & Keith, 1980); 0.6 (min 0.2; max 1.0)/100 km^2 (Smith et al., 2004); 1.1-2.4/100 km^2 (Bjorge & Gunson, 1989)
Black bear (*Ursus americanus)*	39.1 (19.0-80.3) 25.7	19.0; 20.0; 21.0; 21.0; 24.0; 25.0/100 km^2 (Coster et al., 2011); 25.7 (min 17.3; max 45.8)/100km^2 (Mowat et al., 2005); 32.6; 34.4; 38.5; 42.2; 45.4; 53.7; 56.4; 62.4; 62.8; 80.3/100 km^2 (Sargeant and Ruff, 2001)
Grizzly bear (*Ursus arctos*)	1.8 (0.3-8.0) 0.8	0.3/100 km^2 (Kendall et al., 2008); 0.5 (Nielsen, 2007); 0.6; 0.6; 1.4; 1.5; 2.6; 2.9; 3.9; 3.9; 4.8-8.0/100 km^2 in different areas along the Alberta – British Columbia border (review in Proctor et al., 2010); 1.0 (Parks Canada, 2011b)
Woodland caribou (*Rangifer tarandus caribou*)	49.1 (0.8-280.0) 0.9	0.8; 0.9; 0.9; 1.2 (Hebblewhite et al., 2007); 1.6; 2.1; 2.2; 2.9; 3.8; 4.1; 4.6; 7.0; 8.1; 15.2/100km2 (Wittmer et al., 2010); 4.2/100 km^2 (Fuller & Keith, 1981); 7.0; 7.0; 10.0; 10.0; 10.0; 50.0; 50.0; 50.0; 60.0; 70.0; 140.0; 180.0; 180.0; 260.0; 280.0; 280.0/100 km^2 (Weclaw and Hudson, 2004)

Table 3. The sources, areas and regions on which the population density estimates are based. The sources and study areas marked in yellow are considered most representative for JNP and MRPP based on habitat and geographic proximity.

Species	Source	Study area
Fisher (*Martes pennanti*)	O'Neil & Swanson (2010)	north-central Massachusetts, USA
	Heinemeyer & Jones (1994)	Northern Rocky Mountains, USA
	Arthur et al. (1989)	south-central Maine, USA
	Koen et al. (2007)	Ontario, Canada
Wolverine (*Gulo gulo*)	Squires et al. (2007)	western Montana, USA
	Royle et al. (2011)	southeast Alaska, USA
	Hornocker & Hash (1981)	northwestern Montana, USA
Canada lynx (*Lynx canadensis)*	Stenseth et al. (1998)	multiple areas throughout Canada
	Slough & Mowat (1996)	southern Yukon Territory, Canada
	Vashon et al. (2008)	northern Maine, USA
Cougar (*Puma concolor)*	Lambert et al. (2006)	southwestern British Columbia, Canada and bordering areas, USA
	Ross & Jalkotzky (1992)	southwestern Alberta, Canada
	Spreadbury et al. (1996)	southeastern British Columbia, Canada
Coyote (*Canis latrans*)	Pyrah (1984)	north central Montana, USA
	Todd et al. (1981)	central Alberta, Canada
	Hein & Andelt (1995)	Colorado, USA
Wolf (*Canis lupus*)	Hebblewhite et al. (2007)	Banff and Jasper National Park, Alberta, Canada
	Fuller & Keith (1980)	northern Alberta, Canada
	Smith et al. (2004)	Yellowstone National Park, Wyoming, Montana, Idaho, USA
	Bjorge & Gunson (1989)	west central Alberta, Canada
Black bear (*Ursus americanus)*	Coster et al. (2011)	northern New Hampshire, USA
	Mowat et al. (2005)	east central British Columbia, Canada
	Sargeant and Ruff (2001)	east central Alberta, Canada
Grizzly bear (*Ursus arctos*)	Kendall et al. (2008)	Glacier National Park, Montana, USA
	Nielsen (2007)	Jasper National Park, Alberta, Canada
	Proctor et al. (2010)	multiple areas along the Alberta – British Columbia border, Canada
	Parks Canada (2011b)	Jasper National Park, Alberta, Canada
Woodland caribou (*Rangifer tarandus caribou*)	Hebblewhite et al. (2007)	Banff and Jasper National Park, Alberta, Canada
	Wittmer et al. (2010)	southeastern British Columbia, Canada
	Fuller & Keith (1981)	north east Alberta, Canada
	Weclaw and Hudson (2004)	northern Alberta

Table 4. Surface area (in ha) of the different habitat types in the subareas identified for each population structure scenario. The habitat types and surface areas are based on the Globcover 2009 database (ESA, 2010).

Scenario population structure	Area	Habitat type													Total (ha)
		Open (15-40%) broadleaved deciduous forest/woodland (>5m)	Closed (>40%) needleleaved evergreen forest (>5m)	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	Sparse (<15%) vegetation	Bare areas	Water bodies	Permanent snow and ice	No data (burnt areas, clouds,…)	
		VALUE_60	VALUE_70	VALUE_90	VALUE_100	VALUE_110	VALUE_120	VALUE_130	VALUE_140	VALUE_150	VALUE_200	VALUE_210	VALUE_220	VALUE_230	
Scenario 1	N and S of Hwy 16	967.9	188,212.5	213,548.5	13,321.5	57,568.1	64,068.7	519.0	33,503.8	706,658.9	34.9	11,761.2	58,191.3	590.7	1,348,947.1
Scenario 2	N of Hwy 16	619.9	74,026.6	99,615.6	8,392.3	25,318.0	26,531.9	304.3	13,264.6	251,334.6	0.0	3,757.5	24,026.8	149.2	527,341.4
	S of Hwy 16	348.0	114,185.9	113,933	4,929.2	32,250.1	3,7536.8	214.7	2,0239.2	455,324.3	34.9	8,003.7	34,164.5	441.5	821,605.8
Scenario 3	N of Hwy 16	619.9	74,026.6	99,615.6	8,392.3	25,318.0	26,531.9	304.3	13,264.6	251,334.6	0.0	3,757.5	24,026.8	149.2	527,341.4
	S Hwy 16, E Hwy 93	17.4	41,641.5	64,013.1	846.4	17,791.7	22,736.8	110.1	13,188.7	266,997.4	0.0	4,423.3	4,342.1	179.7	436,288.3
	S Hwy 16, W Hwy 93	330.6	72,544.4	49,919.9	4,082.8	14,458.4	14,800.0	104.6	7,050.5	188,326.9	34.9	3,580.4	29,822.4	261.8	385,317.5

Table 5. The habitat types present in JNP and MRPP and similarity or suitability of the habitat types (in %) in relation to the study areas listed in Table 3.

	Open (15-40%) broadleaved deciduous forest/woodland (>5m)	Closed (>40%) needleleaved evergreen forest (>5m)	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	Sparse (<15%) vegetation	Bare areas	Water bodies	Permanent snow and ice	No data (burnt areas, clouds,…)
Species	VALUE_60	VALUE_70	VALUE_90	VALUE_100	VALUE_110	VALUE_120	VALUE_130	VALUE_140	VALUE_150	VALUE_200	VALUE_210	VALUE_220	VALUE_230
Fisher (*Martes pennanti*)	100%	100%	100%	100%	10%	10%	10%	10%	0%	0%	0%	0%	0%
Wolverine (*Gulo gulo*)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Canada lynx (*Lynx canadensis*)	100%	100%	100%	100%	10%	10%	10%	10%	10%	0%	0%	0%	0%
Cougar (*Puma concolor*)	100%	100%	100%	100%	100%	100%	100%	100%	10%	0%	0%	0%	0%
Coyote (*Canis latrans*)	100%	10%	100%	100%	100%	100%	100%	100%	10%	0%	0%	0%	0%
Wolf (*Canis lupus*)	100%	100%	100%	100%	100%	100%	100%	100%	10%	0%	0%	0%	0%
Black bear (*Ursus americanus*)	100%	100%	100%	100%	100%	100%	100%	10%	0%	0%	0%	0%	0%
Grizzly bear (*Ursus arctos*)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Caribou (*Rangifer tarandus caribou*)	100%	100%	100%	100%	100%	100%	10%	10%	10%	0%	0%	0%	0%

1.2.4: Step 4: Population Persistence

The researchers estimated population persistence for the focal species through a five step approach:

Step 4.1: The researchers transformed the population size estimates for the subareas into estimates for the number of Reproductive Units (RU). A RU is defined as the minimum number of individuals needed for breeding. One RU is usually a breeding pair, but may consist of less than two individuals if males breed with multiple females or more than two individuals when a species forms social groups in which only a limited number of individuals take part in reproduction (Van der Grift & Pouwels, 2006). Two possible situations were evaluated in the analyses: (1) RU = 50% of total (sub)population, and (2) RU = 30% of total (sub)population. These percentages imply that the researchers assumed that respectively 50% and 30% of the population for all focal species consisted of adult females that take part in the reproduction. For the ‘likely’ and ‘actual’ population size the researchers conducted the analyses for 30% RU only.

Step 4.2: For each population structure scenario (see Step 2) two ESLIs were calculated and compared to existing norms for population persistence:

- The number of RUs in the largest (sub)population (ESLI 1)
- The number of RUs in the network population within JNP and MRPP (ESLI 2).

Step 4.3: The researchers assessed whether the largest (sub)population (ESLI 1) could be classified as a Key Population (KP) or a Minimum Viable Population (MVP). A KP was defined as a population in a population network that has a probability of extinction of less than 5% in 100 years, under the condition of at least one immigrant per generation. A MVP was defined as a population that has a probability of extinction of exactly 5% in 100 years, even if it is completely isolated (i.e. without any immigrants). The norms for a KP and MVP were based on existing norms for population persistence for long living mammal species (Verboom et al., 1997; Pouwels et al., 2002):

- Standard key population (KP): ≥40 RU
- Standard minimum viable population (MVP): ≥60 RU

Step 4.4: The researchers compared the population size estimates (in RU) for the network (ESLI 2) to the following standards for long living mammal species (Verboom et al. 1997, Pouwels et al., 2002):

- Standard persistent population network with a MVP: 60 RU
- Standard persistent population network with a KP but without a MVP: 160 RU
- Standard persistent population network without a KP and without a MVP: 240 RU

The standards for KP, MVP and population network persistence were derived from empirical data on population turnover and presence/absence data in combination with dynamic population model simulations in order to investigate how many more RU are needed for a persistent population network if a KP occurs but no MVP or if both a KP and a MVP are lacking. The derivation of the standards used in step 4 and 5 is described in more detail by Verboom et al. (1997 and 2001). Please note that the standards presented in table 5 in Verboom et al. (2001) refer to small, medium-sized and large *bird* species only. The standards for mammals differ slightly and are only presented in the original research report (Verboom et al. 1997).

Step 4.5: The researchers calculated a "score" for the persistence of the network population for each of the focal species by dividing the population size estimate (in RU) of the network (total population size in JNP and MRPP; ESLI 2) by the norm for a persistent population network (either 60, 160 or 240 RU). The following categories were assigned to this score (Pouwels et al., 2002):

<1:	Not persistent (extinction probability >5% in 100 years)
1-5:	Persistent (extinction probability 1-5% in 100 years)
>5:	Highly persistent (extinction probability <1% in 100 years)

Note that the persistence assessment assumes that the network population in JNP and MRPP is not connected to populations that may be present in areas adjacent to JNP and MRPP. In other words, if a population of a focal species is classified as "not persistent" within the network population of JNP and MRPP, the survival of that species within JNP and MRPP is dependent on the presence and size of the populations in the areas outside JNP and MRPP and their connectivity with the populations inside JNP and MRPP. On the other hand, species that were classified as persistent or highly persistent have a persistent network population within the JNP and MRPP and their survival probability is not dependent on the presence and size of populations in areas outside JNP and MRPP.

1.2.5: Impact of Reported and Potential Direct Road and Railroad Mortality

The researchers argue that if a population of a certain species is estimated to be not persistent in the study area that any unnatural mortality is a problem by definition. If a population of a certain species is persistent or highly persistent the researchers encourage managers to also evaluate the percentage of road- and railroad mortality relative to the number of RUs in the network population (ESLI 2). The researchers declared there to be "no problem" if the direct road- and railroad mortality was less than ≤5% of the number of RUs whereas it was declared a problem if the mortality was >5%. This means that if a population is estimated to be persistent or highly persistent based on population size and structure but is estimated to have road-and railroad mortality >5% of the number of RUs in the network population that the researchers still view this as a threat to the persistence of the population.

The researchers calculated the average number of reported road and railroad mortalities per year for the different species in JNP and MRPP based on a ten year time period (Table 6; see also Chapter 3, Table 2). For some species no road or railroad mortality was reported over ten years (resulting in a reported mortality number of 0.0). Since the reported road mortalities are minimum numbers the researchers also investigated the effect of different levels of theoretical road and railroad mortality for the individual focal species; at least one animal per ten years, at least one animal per year, at least 10 animals per year, and at least 20 animals per year) (Table 6). These theoretical levels of direct road and railroad mortality allow for some insight in how population persistence may be affected if slightly more or substantially more animals are hit than reported. For a road in north western Montana, USA, road maintenance crew personnel estimated that of all large mammal carcasses observed along the road only about 80% are removed and reported (Huijser et al., 2006a). Another 30-40% of the deer carcasses are estimated to be removed by others, either legally or illegally. Hesse (2006) and Sielecki (2004) state that the animal carcass reporting system in British Columbia may only report 25% of all carcasses for large mammals. For the purpose of this report the researchers assumed that underreporting may be up to 50% for at least some of the road and railroad sections.

Table 6. Reported and different levels of theoretical road and railroad mortality in JNP and MRPP (Hwy 16, Hwy 93 and the railroad combined). The reported mortalities are averages based on a 10 year period from 1 January 2000 through 31 December 2009 (see Appendix B for the reported mortalities per year).

		Theoretical minimum mortality (per year)			
Focal species	Reported	≥1/10 yrs	≥1/yr	≥10/yr	≥20/yr
Fisher (*Martes pennanti*)	0.0	0.1	1	10	20
Wolverine (*Gulo gulo)*	0.3	0.3	1	10	20
Canada lynx (*Lynx canadensis)*	1.1	1.1	1.1	10	20
Cougar (*Puma concolor)*	0.0	0.1	1	10	20
Coyote (*Canis latrans)*	7.9	7.9	7.9	10	20
Wolf (*Canis lupus*)	4.6	4.6	4.6	10	20
Black bear (*Ursus americanus)*	8.8	8.8	8.8	10	20
Grizzly bear (*Ursus arctos*)	0.0	0.1	1	10	20
Caribou (*Rangifer tarandus caribou*)	0.4	0.4	1	10	20

1.3 Results

1.3.1: Estimated Population Size

The estimates for the average, minimum and maximum population size of the focal species in the (sub)areas are summarized in Table 7. In addition, based on similar habitat and geographic proximity to JNP and MRPP a ‘likely’ population size was calculated for each of the focal species in JNP and MRPP (Table 7). For caribou population counts were available for each of the subareas resulting in an ‘actual’ population size.

Table 7. The estimated average, minimum, maximum, likely, and actual population size of the different species (both sexes, all age categories) in JNP and MRPP in the three subareas and for the three subareas combined. The average, minimum and maximum numbers are based on population densities from other more or less comparable areas (see Table 2). The likely population size is based on studies with most similar habitat and geographical proximity (see Table 2). Actual population size is based on actual counts in each of the three subareas.

Species and subarea	Average	Minimum	Maximum	Likely	Actual
Fisher					
N of Hwy 16	281.9	56.8	675.4	66.2	?
S Hwy 16, E Hwy 93	166.7	33.6	399.5	39.2	?
S Hwy 16, W Hwy 93	194.5	39.2	466.0	45.7	?
Total	643.1	129.5	1540.9	151.1	?
Wolverine					
N of Hwy 16	47.5	5.3	79.1	42.2	?
S Hwy 16, E Hwy 93	39.3	4.4	65.4	34.9	?
S Hwy 16, W Hwy 93	34.7	3.9	57.8	30.8	?
Total	121.4	13.5	202.3	107.9	?
Canada lynx					
N of Hwy 16	225.0	42.9	962.3	117.9	?
S Hwy 16, E Hwy 93	145.5	27.7	622.3	76.2	?
S Hwy 16, W Hwy 93	156.8	29.9	670.6	82.1	?
Total	527.4	100.5	2255.2	276.3	?
Cougar					
N of Hwy 16	71.0	24.6	125.7	71.0	?
S Hwy 16, E Hwy 93	48.6	16.8	86.0	48.6	?
S Hwy 16, W Hwy 93	47.4	16.4	83.8	47.4	?
Total	167.0	57.8	295.5	167.0	?
Coyote					
N of Hwy 16	497.9	144.6	1466.7	391.4	?
S Hwy 16, E Hwy 93	360.5	104.7	1061.9	269.2	?
S Hwy 16, W Hwy 93	281.6	81.8	829.5	206.4	?
Total	1139.9	331.1	3358.2	867.0	?
Wolf					
N of Hwy 16	22.1	5.5	49.2	8.2	?
S Hwy 16, E Hwy 93	15.2	3.7	33.7	5.6	?
S Hwy 16, W Hwy 93	14.8	3.6	32.8	5.5	?
Total	52.1	12.8	115.6	19.3	?

Black bear					
N of Hwy 16	923.3	448.7	1896.2	606.9	?
S Hwy 16, E Hwy 93	580.5	282.1	1192.3	381.6	?
S Hwy 16, W Hwy 93	613.7	298.2	1260.3	403.4	?
Total	2117.5	1029.0	4348.7	1391.8	?
Grizzly bear					
N of Hwy 16	94.9	15.8	421.9	42.2	?
S Hwy 16, E Hwy 93	78.5	13.1	349.0	34.9	?
S Hwy 16, W Hwy 93	69.4	11.6	308.3	30.8	?
Total	242.8	40.5	1079.2	107.9	?
Caribou					
N of Hwy 16	1281.5	20.9	7307.9	44.9	150
S Hwy 16, E Hwy 93	859.6	14.0	4902.1	38.5	17
S Hwy 16, W Hwy 93	862.6	14.1	4919.2	31.6	54
Total	3003.7	48.9	17129.2	115.1	221

1.3.2: Estimated Number of Reproductive Units and Population Persistence

The three population size estimates (minimum, average, maximum) and the two percentages for the number of RUs in the population (30%, 50%) resulted in six possible combinations (Table 8) and corresponding number of RUs.

Wolves do not have a persistent population in any of the six combinations regardless of whether Hwy 16 and 93 are at least somewhat of a barrier to their movements (Table 8). Wolverine and cougar have non-persistent populations for most combinations, except the most optimistic ones with high population density, 50% of the population consisting of reproductive females and Hwy 93 or both Hwy 16 and 93 not acting as a barrier. Grizzly bear also benefit from Hwy 93 and Hwy 16 not hindering their movements with persistent populations under average population density. Fisher, Canada lynx, coyote and caribou have persistent populations, except under the most pessimistic combinations and scenarios. The black bear population is estimated to be highly persistent under all combinations and scenarios.

For the likely population densities in JNP and MRPP fisher, wolverine, cougar, grizzly bear and caribou do not have persistent populations, regardless of whether Hwy 93 and Hwy 16 act as a barrier to their movements (Table 9). However, based on actual population counts of caribou, this species is estimated to have a persistent population if both Hwy 93 and Hwy 16 do not act as a barrier. Canada lynx may also have a persistent population if the two highways do not hinder their movements. Coyote and black bear are estimated to have persistent or highly persistent populations regardless of whether Hwy 93 and Hwy 16 are a barrier to their movements.

Table 8. The estimated population persistence for the focal species for different estimates for population density (minimum, average and maximum) and different estimates on the percentage reproductive units in the population (30% and 50%).

Species	Min. 30%	Min. 50%	Ave. 30%	Ave. 50%	Max. 30%	Max. 50%
Scenario 1 **Hwy 16 and Hwy 93 are both not a barrier**						
Fisher (*Martes pennanti*)	[red]	[light green]	[light green]	[dark green]	[dark green]	[dark green]
Wolverine (*Gulo gulo*)	[red]	[red]	[red]	[light green]	[light green]	[light green]
Canada lynx (*Lynx canadensis*)	[red]	[red]	[light green]	[light green]	[dark green]	[dark green]
Cougar (*Puma concolor*)	[red]	[red]	[red]	[light green]	[light green]	[light green]
Coyote (*Canis latrans*)	[light green]	[light green]	[dark green]	[dark green]	[dark green]	[dark green]
Wolf (*Canis lupus*)	[red]	[red]	[red]	[red]	[red]	[red]
Black bear (*Ursus americanus*)	[dark green]	[dark green]	[dark green]	[dark green]	[dark green]	[dark green]
Grizzly bear (*Ursus arctos*)	[red]	[red]	[light green]	[light green]	[dark green]	[dark green]
Caribou (*Rangifer tarandus caribou*)	[red]	[red]	[dark green]	[dark green]	[dark green]	[dark green]
Scenario 2 **Hwy 16 is a barrier, Hwy 93 is not a barrier**						
Fisher (*Martes pennanti*)	[red]	[red]	[light green]	[dark green]	[dark green]	[dark green]
Wolverine (*Gulo gulo*)	[red]	[red]	[red]	[red]	[red]	[light green]
Canada lynx (*Lynx canadensis*)	[red]	[red]	[light green]	[light green]	[dark green]	[dark green]
Cougar (*Puma concolor*)	[red]	[red]	[red]	[red]	[red]	[light green]
Coyote (*Canis latrans*)	[red]	[light green]	[dark green]	[dark green]	[dark green]	[dark green]
Wolf (*Canis lupus*)	[red]	[red]	[red]	[red]	[red]	[red]
Black bear (*Ursus americanus*)	[dark green]	[dark green]	[dark green]	[dark green]	[dark green]	[dark green]
Grizzly bear (*Ursus arctos*)	[red]	[red]	[red]	[light green]	[dark green]	[dark green]
Caribou (*Rangifer tarandus caribou*)	[red]	[red]	[dark green]	[dark green]	[dark green]	[dark green]
Scenario 3 **Hwy 16 and Hwy 93 are both a barrier**						
Fisher (*Martes pennanti*)	[red]	[red]	[light green]	[dark green]	[dark green]	[dark green]
Wolverine (*Gulo gulo*)	[red]	[red]	[red]	[red]	[red]	[red]
Canada lynx (*Lynx canadensis*)	[red]	[red]	[light green]	[light green]	[dark green]	[dark green]
Cougar (*Puma concolor*)	[red]	[red]	[red]	[red]	[red]	[light green]
Coyote (*Canis latrans*)	[red]	[light green]	[dark green]	[dark green]	[dark green]	[dark green]
Wolf (*Canis lupus*)	[red]	[red]	[red]	[red]	[red]	[red]
Black bear (*Ursus americanus*)	[dark green]	[dark green]	[dark green]	[dark green]	[dark green]	[dark green]
Grizzly bear (*Ursus arctos*)	[red]	[red]	[red]	[red]	[light green]	[dark green]
Caribou (*Rangifer tarandus caribou*)	[red]	[red]	[dark green]	[dark green]	[dark green]	[dark green]

[red]	Not persistent	RU < norm
[light green]	Persistent	RU ≥1 and ≤5 times norm
[dark green]	Highly persistent	RU > 5 times norm

Table 9. The estimated population persistence for the focal species based on the likely population density in JNP and MRPP (all species) and based on actual population counts (caribou only) and assuming the percentage of reproductive units in the population to be 30%.

Species	Scenario		
	Scenario 1 **No road/railroad barriers**	**Scenario 2** **Hwy 16 barrier**	**Scenario 3** **Hwy 16 and 93 barrier**
Fisher (*Martes pennanti*)	Not persistent	Not persistent	Not persistent
Wolverine (*Gulo gulo*)	Not persistent	Not persistent	Not persistent
Canada lynx (*Lynx canadensis*)	Persistent	Not persistent	Not persistent
Cougar (*Puma concolor*)	Not persistent	Not persistent	Not persistent
Coyote (*Canis latrans*)	Persistent	Persistent	Persistent
Wolf (*Canis lupus*)	Not persistent	Not persistent	Not persistent
Black bear (*Ursus americanus*)	Highly persistent	Highly persistent	Highly persistent
Grizzly bear (*Ursus arctos*)	Not persistent	Not persistent	Not persistent
Caribou (*Rangifer tarandus caribou*)*1	Not persistent	Not persistent	Not persistent
Caribou (*Rangifer tarandus caribou*)*2	Persistent	Not persistent	Not persistent

[red]	Not persistent	RU < norm
[light green]	Persistent	RU ≥1 and ≤5 times norm
[dark green]	Highly persistent	RU ≥5 times norm
*1	Based on population density south of Hwy 16	
*2	Based on actual counts in each of the three subareas	

1.3.3: Road and Railroad Mortality vs. Reproductive Units

The average annual reported road and railroad mortality in JNP and MRPP was less than 5% of the number of reproductive units for most of the six combinations and scenarios for most of the species (Table 10). Wolf was an exception; even in the most optimistic combination and scenario direct road and railroad mortality was more than 5% of the number of reproductive units. Coyote and wolverine only reached this value for the most pessimistic combination and scenario. None of the species had reported road and railroad mortality exceed 5% of the RU without already having been identified as having a non-persistent population in at least one of the three scenarios for the barrier effect of the highways.

With higher theoretical road and railroad mortality (≥0.1 or ≥1 mortalities/year) cougar, grizzly bear and caribou also start reaching the 5% threshold for some of the combinations and scenarios. At even higher theoretical road and railroad mortality (≥10 or ≥20 mortalities per year) all remaining species reach the 5% threshold for at least some of the combinations and scenarios. For some species, some combinations of population size estimates and percentage of RUs had the theoretical road and railroad mortality levels exceed 5% of the RU without already having been identified as having a non-persistent population in at least one of the three scenarios for the barrier effect of the highways. However, this only occurred at theoretical mortality that was 10 or more individuals per year.

Assuming a 'likely' population density, the average annual reported road and railroad mortality in JNP and MRPP was less than 5% of the number of reproductive units for most of the focal species (Table 11). Wolf was an exception though. The other focal species, except black bear, only reach the 5% threshold if at least 10 or 20 individuals are hit per year. These numbers are only reached if there is substantial underreporting on all or some of the road and railroad sections through JNP and MRPP. Black bear road and railroad mortality did not reach the 5% threshold with any of the reported or theoretical mortality levels for any of the combinations. Only coyote had the theoretical road and railroad mortality levels exceed 5% of the RU without already having been identified as having a non-persistent population in at least one of the three scenarios for the barrier effect of the highways. However, this only occurred at theoretical mortality that was 20 or more individuals per year.

Table 10. The reported and theoretical road and railroad mortality expressed as a percentage of the estimated number of reproductive units for different estimates for population density (minimum, average and maximum) and different estimates on the percentage reproductive units in the population (30% and 50%). The colors represent different combinations for population persistence and road and railroad mortality.

Species	Mortality (% of RU)					
Reported mortality	**Min. 30%**	**Min. 50%**	**Aver. 30%**	**Aver. 50%**	**Max. 30%**	**Max. 50%**
Fisher (*Martes pennanti*)	0.0	0.0	0.0	0.0	0.0	0.0
Wolverine (*Gulo gulo*)	7.4	4.4	0.8	0.5	0.5	0.3
Canada lynx (*Lynx canadensis*)	3.7	2.2	0.7	0.4	0.2	0.1
Cougar (*Puma concolor*)	0.0	0.0	0.0	0.0	0.0	0.0
Coyote (*Canis latrans*)	8.0	4.8	2.3	1.4	0.8	0.5
Wolf (*Canis lupus*)	119.3	71.6	29.4	17.7	13.3	8.0
Black bear (*Ursus americanus*)	2.9	1.7	1.4	0.8	0.7	0.4
Grizzly bear (*Ursus arctos*)	0.0	0.0	0.0	0.0	0.0	0.0
Caribou (*Rangifer tarandus caribou*)	2.7	1.6	0.0	0.0	0.0	0.0
Theoretical mortality ≥1/10 yrs						
Fisher (*Martes pennanti*)	0.3	0.2	0.1	0.0	0.0	0.0
Wolverine (*Gulo gulo*)	7.4	4.4	0.8	0.5	0.5	0.3
Canada lynx (*Lynx canadensis*)	3.7	2.2	0.7	0.4	0.2	0.1
Cougar (*Puma concolor*)	0.6	0.3	0.2	0.1	0.1	0.1
Coyote (*Canis latrans*)	8.0	4.8	2.3	1.4	0.8	0.5
Wolf (*Canis lupus*)	119.3	71.6	29.4	17.7	13.3	8.0
Black bear (*Ursus americanus*)	2.9	1.7	1.4	0.8	0.7	0.4
Grizzly bear (*Ursus arctos*)	0.8	0.5	0.1	0.1	0.0	0.0
Caribou (*Rangifer tarandus caribou*)	2.7	1.6	0.0	0.0	0.0	0.0
Theoretical mortality ≥1/yr						
Fisher (*Martes pennanti*)	2.6	1.5	0.5	0.3	0.2	0.1
Wolverine (*Gulo gulo*)	24.7	14.8	2.7	1.6	1.6	1.0
Canada lynx (*Lynx canadensis*)	3.7	2.2	0.7	0.4	0.2	0.1
Cougar (*Puma concolor*)	5.8	3.5	2.0	1.2	1.1	0.7
Coyote (*Canis latrans*)	8.0	4.8	2.3	1.4	0.8	0.5
Wolf (*Canis lupus*)	119.3	71.6	29.4	17.7	13.3	8.0
Black bear (*Ursus americanus*)	2.9	1.7	1.4	0.8	0.7	0.4
Grizzly bear (*Ursus arctos*)	8.2	4.9	1.4	0.8	0.3	0.2
Caribou (*Rangifer tarandus caribou*)	6.8	4.1	0.1	0.1	0.0	0.0

Table 10 - Continued						
Species	**Mortality (% of RU)**					
Theoretical mortality ≥10/yr	**Min. 30%**	**Min. 50%**	**Aver. 30%**	**Aver. 50%**	**Max. 30%**	**Max. 50%**
Fisher (*Martes pennanti*)	25.7	15.4	5.2	3.1	2.2	1.3
Wolverine (*Gulo gulo*)	247.1	148.3	27.5	16.5	16.5	9.9
Canada lynx (*Lynx canadensis*)	33.2	19.9	6.3	3.8	1.5	0.9
Cougar (*Puma concolor*)	57.7	34.6	20.0	12.0	11.3	6.8
Coyote (*Canis latrans*)	10.1	6.0	2.9	1.8	1.0	0.6
Wolf (*Canis lupus*)	259.5	155.7	64.0	38.4	28.8	17.3
Black bear (*Ursus americanus*)	3.2	1.9	1.6	0.9	0.8	0.5
Grizzly bear (*Ursus arctos*)	82.4	49.4	13.7	8.2	3.1	1.9
Caribou (*Rangifer tarandus caribou*)	68.1	40.9	1.1	0.7	0.2	0.1
Theoretical mortality ≥20/yr						
Fisher (*Martes pennanti*)	51.5	30.9	10.4	6.2	4.3	2.6
Wolverine (*Gulo gulo*)	494.2	296.5	54.9	32.9	32.9	19.8
Canada lynx (*Lynx canadensis*)	66.4	39.8	12.6	7.6	3.0	1.8
Cougar (*Puma concolor*)	115.3	69.2	39.9	23.9	22.6	13.5
Coyote (*Canis latrans*)	20.1	12.1	5.8	3.5	2.0	1.2
Wolf (*Canis lupus*)	518.9	311.3	128.0	76.8	57.7	34.6
Black bear (*Ursus americanus*)	6.5	3.9	3.1	1.9	1.5	0.9
Grizzly bear (*Ursus arctos*)	164.7	98.8	27.5	16.5	6.2	3.7
Caribou (*Rangifer tarandus caribou*)	136.2	81.7	2.2	1.3	0.4	0.2

Color	**Problem?**	**Population persistence**	**Mortality**
(dark red)	Yes	Not persistent in scenario 1, 2 or 3	Mortality >5% of RU
(red)	Yes	Not persistent in scenario 1, 2 or 3	Mortality ≤5% of RU
(orange)	Yes	Persistent/highly persistent in all scenarios	Mortality >5% of RU
(green)	No	Persistent/highly persistent in all scenarios	Mortality ≤5% of RU

Table 11: The reported and theoretical road and railroad mortality expressed as a percentage of the estimated number of reproductive units based on the likely population size in JNP and MRPP and the percentage reproductive units in the population assumed to be 30%.

Species	Reported (% of RU)	Theoretical minimum mortality (% of RU)			
		1/10 yrs	1/yr	10/yr	20/yr
Fisher (*Martes pennanti*)	0.0	0.2	2.2	22.1	44.1
Wolverine (*Gulo gulo*)	0.9	0.9	3.1	30.9	61.8
Canada lynx (*Lynx canadensis*)	1.3	1.3	1.3	12.1	24.1
Cougar (*Puma concolor*)	0.0	0.2	2.0	20.0	39.9
Coyote (*Canis latrans*)	3.0	3.0	3.0	3.8	7.7
Wolf (*Canis lupus*)	79.6	79.6	79.6	173.0	345.9
Black bear (*Ursus americanus*)	2.1	2.1	2.1	2.4	4.8
Grizzly bear (*Ursus arctos*)	0.0	0.3	3.1	30.9	61.8
Caribou (*Rangifer tarandus caribou*)*1	1.2	1.2	2.9	29.0	57.9
Caribou (*Rangifer tarandus caribou*)*2	0.6	0.6	1.5	15.1	30.2

Color	Problem?	Population persistence	Mortality
(dark red)	Yes	Not persistent in scenario 1, 2 or 3	Mortality >5% of RU
(red)	Yes	Not persistent in scenario 1, 2 or 3	Mortality ≤5% of RU
(orange)	Yes	Persistent/highly persistent in all scenarios	Mortality >5% of RU
(green)	No	Persistent/highly persistent in all scenarios	Mortality ≤5% of RU

*1	Based on population density south of Hwy 16
*2	Based on actual counts in each of the three subareas

1.4 Discussion and Conclusion

The researchers considered a range of possible population densities and therefore possible population sizes for the focal species in JNP and MRPP. The researchers also considered different percentages of the population to consist of reproductive females (RU is either 30% or 50%) and considered the two main roads to be either at least somewhat of a barrier to the movements of the focal species or not at all. Each combination of population size estimate and percentage of RUs and each population structure scenario resulted in an estimate for the population persistence of the focal species. Based on the results one may conclude that it is more likely or less likely that an individual focal species has a persistent population in JNP or MRPP if the two parks are considered an island and isolated from potential populations in the adjacent areas.

In all of the combinations and scenarios and under all assumptions wolf seems to be especially vulnerable and direct road and railroad mortality appears to be relatively high compared to the number of reproductive units and their population size. Fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou may or may not have persistent populations in JNP and MRPP depending on the scenario and assumptions one chooses to accept. The population persistence of the species listed above may well depend on the presence, size, and connectivity with populations in the areas adjacent to JNP and MRPP. One could argue that any road or railroad mortality that occurs would be undesirable for these species and that it further threatens their population persistence within the two parks. This could provide a framework, rationale or justification to implement mitigation measures along the road and railroad for these species. Coyote and black bear are most likely to have persistent populations in JNP and MRPP and may not be affected very much by direct road and railroad mortality.

The method used for assessing population persistence can be characterized as a “quick-scan”. The advantage of this quick scan method is that selected areas can be evaluated relatively quickly and easily for the population persistence of a multitude of species. The disadvantage of the quick scan method is of course a relatively high level of uncertainty. The use of a simple set of rules and standards makes the method sensitive to small alterations in the parameter values. The researchers at least partly counteracted this disadvantage through calculating population persistence for a range of parameter combinations reflecting a spread from worst-case to best-case scenarios. This provides insight in the robustness of the outcomes for the combinations and scenarios that are assumed to reflect reality best. Another disadvantage is that the use of standards (thresholds) results in a “black and white” type of assessment. This should be taken into account when interpreting the outcomes, especially when parameter values almost or just meet the thresholds. Because of these disadvantages of the method, the outcome of the assessment should never be interpreted as a precise but rather an indicative prediction of population persistence within JNP and MRPP.

The researchers suggest conducting more extensive and formal population viability analyses (PVAs), using dynamic (meta)population models, especially for the wolf, but also for fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou. Coyote and black bear can be considered less of a priority for further research. Alternatively one can use the results of the current study as a rationale to start implementing mitigation measures aimed at reducing direct road and railroad mortality and providing safe crossing opportunities for wildlife, especially for wolf, fisher, wolverine, Canada lynx, cougar, grizzly bear and caribou.