ANIMAL-VEHICLE COLLISIONS AND HABITAT CONNECTIVITY ALONG MONTANA HIGHWAY 83 IN THE SEELEY SWAN VALLEY, MONTANA: A RECONNAISSANCE

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FEDERAL HIGHWAY ADMINISTRATION

February 2006

prepared by

Marcel P. Huijser, Ph.D.
Kari E. Gunson
Carla Abrams

Western Transportation Institute
Montana State University

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Animal-Vehicle Collisions and Habitat Connectivity along Montana Highway 83 in the Seeley-Swan Valley, Montana: a Reconnaissance

by

Marcel P. Huijser, Ph.D., Research Ecologist,
Kari E. Gunson, M.Sc., Research Ecologist and GIS specialist &
Carla Abrams, M.Sc., Field Technician

Western Transportation Institute
College of Engineering, Montana State University
PO Box 174250, Bozeman, MT 59717-4250

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Montana Highway 83 in northwestern Montana, USA, is known for its great number of animal-vehicle collisions, mostly with white-tailed deer (Odocoileus virginianus). This document reports on the first phase of an effort to produce an effective implementation plan that has broad support from natural resource management agencies as well as the local community. Phase 1 is aimed at acquiring information and at identifying potential additional research and resource needs. This document identifies and ranks high-frequency zones for white-tailed deer-vehicle collisions, identifies road- and landscape characteristics associated with white-tailed deer-vehicle collisions, identifies and ranks (additional) habitat linkage zones based on expert knowledge, and identifies and documents additional research and resource needs that may need to be addressed before proceeding with the following phases of an effort to produce an effective implementation plan that has broad support.</td></tr>
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. EXECUTIVE SUMMARY

Montana Highway 83 (MT 83) in northwestern Montana, USA, is known for its great number of animal-vehicle collisions, mostly with white-tailed deer (*Odocoileus virginianus*). The number of recorded wildlife-vehicle collisions is 2.8 times that of the state average for this road type. In addition, 26.1% of all road accidents on MT 83 involve wildlife while the state average is 17.2% for this road type.

The Montana Department of Transportation (MDT) requested the Western Transportation Institute at Montana State University (WTI-MSU) to explore the possibilities to reduce animal-vehicle collisions and improve habitat connectivity for selected animal species along this road. WTI-MSU proposed a stepwise approach with four phases. Input and feedback from natural resource management organizations and the local community characterizes the approach. It is aimed at producing an effective implementation plan that has broad support from natural resource management agencies as well as the local community. Phase 1 is aimed at acquiring information and at identifying potential additional research and resource needs. With this information, species- and site-specific mitigation strategies and options will be formulated in phase 2, and phase 3 is aimed at consensus building with natural resource management agencies and the local community. This should ultimately lead to a concrete and effective implementation plan that has broad support (Phase 4). This document reports on the first phase: the acquisition of information and the identification of additional needs. More specifically, Phase 1 consisted of the following tasks:

- Identify and rank high-frequency zones for animal-vehicle collisions
- Identify road- and landscape characteristics associated with animal-vehicle collisions
- Identify and rank (additional) habitat linkage zones
- Identify and document additional research and resource needs

Analyses of road-kill datasets from MDT showed that 94.5% of all reported road-killed animals along MT 83 are white-tailed deer. The MDT datasets and a dataset on animal-vehicle collisions from the Montana Highway Patrol (MHP) showed that animal-vehicle collisions, especially with white-tailed deer, occur along almost the entire length of the transportation corridor. This was confirmed by individuals with local knowledge and experience. The MHP dataset suggested that the number of animal-vehicle collisions along MT 83 may have increased between 1993 and 2000 and then stabilized at a similar or slightly lower level. Despite differences between the data sets and their limitations, the MDT and MHP data sets all qualified as “monitoring data” with consistent search and reporting effort for individual road sections rather than “incidental observations”.

Certain sections of MT 83 have a higher frequency of white-tailed deer or deer (*Odocoileus sp.*) - collisions than other sections. Based on the MDT dataset, the team identified 27 road sections on MT 83 with a relatively high frequency of white-tailed deer- or deer-vehicle collisions. Of these 27 road sections 17 had at least partial overlap with high frequency collision road sections identified based on the MHP dataset. Mitigation measures aimed at avoiding or reducing animal-vehicle collisions or white-tailed deer- or deer-vehicle collisions in specific, should prioritize these road sections above others.

We recorded a wide range of road-, traffic-, and landscape variables in low and high frequency white-tailed deer collision zones on MT 83 to investigate whether they may be associated with white-tailed deer-vehicle collisions. We recorded the variables both through using a Geographical Information System (GIS) and through direct field observations. High frequency white-tailed deer collision zones were associated with edge habitat, riparian habitat, shrubland, buildings, and relatively high landscape heterogeneity and landscape diversity in a 100 m wide zone on either side of the road. The high frequency collision zones were also associated with edge habitat in a zone adjacent to the road that extended up to 500 and 1000 m on either side of the road. These results may further help identify and prioritize locations along MT 83 that require mitigation for white-tailed deer-vehicle collisions. The findings may also lead to a discussion on the current and future habitat types, land use, and land management in a zone adjacent to MT 83 and how this may ensure the long term effectiveness of potential mitigation measures.

Comparison of the animal-vehicle collision data reported by MDT with expert based identification of high-frequency collision areas suggested that large ungulates other than deer, e.g. elk (*Cervus elaphus*) and relatively rare carnivores, e.g. grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), mountain lions (*Felis concolor*), Canada lynx (*Lynx canadensis*), are underrepresented in animal-vehicle collision data collected by MDT and law enforcement agencies (MHP). Carcasses of relatively small species, e.g. amphibians, turtles, pine marten (*Martes americana*), fisher (*Martes pennanti*), golden eagle (*Aquila chrysaetos*), and bald eagle (*Haliaeetus leucocephalus*), are not recorded by MDT. While most of the smaller species are mostly a conservation concern, the larger species, especially the relatively abundant elk, are also a safety concern.

Individuals with local knowledge and expertise identified certain sections of MT 83 as having a higher frequency of animal crossings than other sections. These areas were marked on 1:24,000 topographical maps. Mitigation measures aimed at reducing the barrier effect of the road for selected species and reducing potential future animal-vehicle collisions should prioritize these road sections above others. However, additional information may be needed to verify that those locations are indeed high frequency crossing and/or collision areas for the species identified.

Changes in land use and management and supplementary feeding of wild animals including deer are thought to have led to a concentration of deer or a higher deer population size along MT 83. In addition, at least part of the white-tailed deer population is thought to have abandoned seasonal migration. The increase in the number of deer present along the transportation corridor and the year-round exposure to traffic is likely to have contributed to an increase in deer-vehicle collisions, especially between 1993 and 1996. Changes in land use and management and supplementary feeding of wild animals are also thought to have led to changes in animal distribution and animal movement patterns (daily, seasonal and dispersal). Therefore road sections with a relatively high frequency of animal-vehicle collisions and animal crossings may reflect where animals were killed and used to cross MT 83 rather than where they do so now.

Before proceeding with the formulation of species- and site-specific mitigation strategies and options (Phase 2), WTI suggests creating a predictive model for high frequency white-tailed deer-vehicle collisions based on the results for phase 1, task 2. Currently the central section of MT 83 (Reference Post (RP) 47.8-80.0) lacks spatially precise animal-vehicle collision data. As a consequence, the current identification of high frequency white-tailed deer collision zones is relatively coarse. The predictive model would allow researchers to increase the spatial resolution of the high frequency collision zones on this road section and reduce the chance of deploying potential future mitigation measures in the wrong places. In addition, WTI suggests interviewing additional individuals with local knowledge and experience, especially species experts for all the species for which the current level of habitat connectivity should be improved or maintained. These species and species groups include bull trout, amphibians, turtles, small mammals, pine marten, fisher, wolverine, deer, elk, Canada lynx, mountain lion, black bear, and grizzly bear.

For certain species the available local knowledge may be too limited to reliably identify high frequency collision or crossing zones. If the reduction of animal-vehicle collisions and the improvement of habitat connectivity across MT 83 are considered very important to the long term survival of such a species, spatial modeling of important habitat and habitat linkage zones may be advisable. Field studies on the particular movements and habits of these species in relation to the transportation corridor and landscape features in the Seeley-Swan Valley may also provide valuable information to help guide recommendations. However, it may take many years to answer certain questions through field studies, and the population survival probability of certain species may have dropped below a critical threshold already by the time those data may become available.

WTI also documented the opinions and ideas of individuals with local knowledge and experience with regard to potential additional research and resource needs. Specific recommendations and considerations were listed with regard to further preparations for a site- and species-specific mitigation plan and the management and future monitoring of road-killed animals and animal-vehicle collisions. Potential mitigation measures, especially wildlife crossing structures, should preferably be based on an integrated approach that includes the traffic, road, right-of-way, and the lands adjacent to the transportation corridor. This may require partnering with natural resource management agencies and private landowners and land users to initiate a discussion on the current and future habitat types, land use and land management in a zone adjacent to MT 83 and how this may ensure the long term effectiveness of potential mitigation measures.

2. INTRODUCTION

The Seeley-Swan Valley in northwestern Montana is a forested area located between the Swan Range to the east and the Mission Mountains to the west (Figure 2.1). The high elevation areas are predominantly designated wilderness while the lands in the valley bottom are mostly a mixture of multiple use National and State Forest lands, and Plum Creek timberlands (Black, 2002). In addition, there is a National Wildlife Refuge, and there are lands owned by The Nature Conservancy, and other private lands. Logging and motorized and non-motorized recreation are important activities in the Seeley-Swan Valley. The valley is bisected by Montana Highway 83 (MT 83), a 146.6 km (91.1 mi) two lane road.

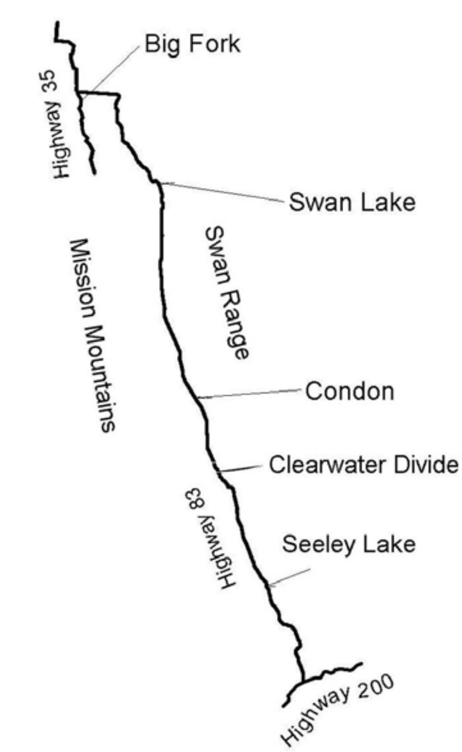


Figure 2-1: Montana Highway 83 bisects the Seeley-Swan valley in northwestern Montana

The number of wildlife-vehicle collisions on MT 83 is thought to be relatively high, especially for white-tailed deer (*Odocoileus virginianus*) (Pat Basting and Dave Galt, Montana Department of Transportation (MDT), pers. com.). WTI verified and quantified this statement by comparing the number of wildlife-vehicle collisions on MT 83 with the state average for this road type (i.e. State Primary Routes) using MDT's database on statewide accident statistics. There were 2,647 recorded wildlife-vehicle collisions on 2815 miles of State Primary Routes in Montana between 1995 and 2004. This translated into 0.09 recorded wildlife-vehicle collisions per mile per year (Table 2-1). Similarly, there were 224 recorded wildlife-vehicle collisions on 91.1 miles of MT 83 between 1995 and 2004. This translated into 0.25 recorded wildlife-vehicle collisions per mile per year, 2.8 times that of the state average for this road type (Table 2-1). In addition, researchers evaluated the percentage collisions related to wildlife (% of the total number of road accidents). There were 15,390 recorded road accidents on 2815 miles of State Primary Routes between 1995 and 2004, and 17.2% (n=2,647) of these accidents were wildlife related (Table 2-1). Similarly, there were 857 recorded road accidents on 91.1 miles of MT 83 between 1995 and 2004, and 26.1% (n=224) of these accidents were wildlife related. Thus, the percentage of collisions related to wildlife on MT 83 was also higher than the state average for this road type.

The Montana Department of Transportation (MDT) normally evaluates road sections that may require safety improvements with regard to four parameters: crash rate, severity index, severity rate, and the number of human fatalities per 0.5 miles over a 10 year period (for further definitions and formula see Montana Department of Transportation (in prep.)). Based on the available funding, MDT sets new "trigger values" for these parameters each year (pers. com. Tom Hanek, MDT). If the values for a certain road section are higher than these trigger values, the location is studied to identify potential measures that may increase safety. The trigger values for 2004 are listed in Table 2-1. For MT 83 as a whole, none of the parameters reached the 2004 trigger values (Table 2-1). However, the trigger values for crash rate, severity rate and the number of human fatalities per 0.5 mile over a 10 year period, are normally applied to relatively short road sections (e.g. 0.5 mile) rather than averaged over long road sections, as in this case (91.1 miles). Averaging over long road sections results in relatively low values for these parameters by definition. The severity index is not influenced by the length of the investigated road section though. The data in Table 2-1 also show that the severity index for all road accidents on MT 83 is higher than for wildlife-vehicle collisions alone, indicating that wildlife-vehicle collisions along MT 83 are less severe than the average road accident along MT 83. The other parameters, crash rate, severity rate, and number of human fatalities per 0.5 mi over a 10 year period, are influenced by the total number of road accidents or human fatalities, making a comparison between all road accidents and wildlife-vehicle collisions alone not meaningful for these parameters.

Table 2-1: Accident statistics (1995-2004) for all road accidents on MT 83, wildlife-vehicle collisions only on MT 83, and state averages for this road type (State Primary Routes) in Montana and trigger values for 2004 (see text).

Parameter	State average or trigger value	All road accidents on MT 83	Wildlife-vehicle collisions on MT 83	Higher than state average or trigger value?
Number of wildlife-vehicle collisions (number per mi per year)	0.09*1	Not applicable	0.25	Yes
Percentage collisions related to wildlife (% of all road accidents)	17.2*1	Not applicable	26.1	Yes
Crash rate	≥4.50*2	1.79	0.49	No
Severity index	≥5.0*2	2.41	1.57	No
Severity rate	≥17.5*2	4.31	0.77	No
Number of human fatalities (number per 0.5 mi per 10 years)	≥3*2	0.08	0.005	No

*1: State average; *2: Trigger value

The relatively high number of wildlife-vehicle collisions is not just a concern for the deer population. The area surrounding MT 83 is also part of the Northern Continental Divide Ecosystem (NCDE) and home to one of the most important remaining grizzly bear (*Ursus arctos*) populations south of the Canadian border (Mace *et al.*, 1996; Servheen *et al.*, 2003). It is also considered important habitat for other rare or endangered forest carnivores such as Canada lynx (*Lynx canadensis*) (Squires & Laurion, 2000), and an important region for the endangered bull trout (*Salvelinus confluentus*) (Baxter *et al.*, 1999).

Endangered species such as grizzly bears have been killed on MT 83 (Pat Basting, MDT, pers. com.). Grizzly bears also tend to avoid major roads and MT 83 is considered a barrier to their movements (Mace *et al.*, 1996; Proctor, 2003). Roads may also be a barrier for Canada lynx movements (Ruediger *et al.*, 2000; Clevenger *et al.*, 2002), but there is little evidence for that in the Seeley-Swan valley (pers. com John Squires, Rocky Mountain Research Station, US Forest Service). Canada lynx are known to cross MT 83 around the Clearwater Divide (pers. com John Squires, Rocky Mountain Research Station, US Forest Service). The “Clearwater Divide” (see Figure 2.1) is the division between the Clearwater River and Swan River watershed near Summit Lake. It is thought that the reason Canada lynx may not frequently cross MT 83 elsewhere is that most of MT 83 is at lower elevation and is therefore not surrounded by typical Canada lynx habitat (pers. com John Squires, Rocky Mountain Research Station, US Forest Service). Furthermore, dams, narrow culverts and other barriers in streams, including those at road crossings, can be a barrier for some fish species such as bull trout (Dunham & Rieman, 1999; Neraas & Spruell, 2001), which may fragment their populations and lead to reduced survival probability. Bull trout also suffer from competition from and hybridization with other (non-native) fish species and erosion from various sources, including roads and logging activities (Baxter *et al.*, 1999).

The Montana Department of Transportation (MDT) requested the Western Transportation Institute at Montana State University (WTI-MSU) to explore the possibilities to reduce wildlife-vehicle collisions while improving or maintaining habitat connectivity for selected animal species along this road. The potential benefits of fewer wildlife-vehicle collisions include fewer human injuries and human fatalities, less property damage to vehicles, and reduced removal and disposal costs for animal carcasses. In addition, some wildlife species, including white-tailed deer, represent a monetary value for hunting and recreational wildlife viewing. This value is lost once an animal is killed on the road. The potential benefit of improving or maintaining habitat connectivity for selected animal species is that the population survival probability of the selected species can be improved, or at least not further affected. This not only has the potential to result in healthier wildlife populations and a healthier ecosystem, but it may also result in streamlining of the environmental review process of infrastructure related projects in the Seeley-Swan valley.

WTI proposed a stepwise approach with four phases (Huijser, 2004). Input and feedback from natural resource management organizations and the local community characterizes the approach. It is aimed at producing an effective implementation plan that has broad support from natural resource management agencies as well as the local community. Phase 1 is aimed at acquiring information and at identifying potential additional research and resource needs. With this information, species- and site-specific mitigation strategies and options may be formulated in Phase 2, and Phase 3 is aimed at consensus building with natural resource management agencies and the local community. This should ultimately lead to a concrete and effective implementation plan that has broad support (Phase 4).

This document reports on the first phase: the acquisition of information and the identification of additional needs. More specifically, Phase 1 consisted of the following tasks:

- Identify and rank high-frequency zones for animal-vehicle collisions
- Identify road- and landscape characteristics associated with animal-vehicle collisions
- Identify and rank (additional) habitat linkage zones
- Identify and document additional research and resource needs

The four tasks listed above are reported on in individual chapters (Chapter 4 through Chapter 7). These chapters are preceded by a chapter that briefly discusses previous and ongoing activities relevant to animal-vehicle collisions and habitat connectivity in the Seeley-Swan Valley (Chapter 3).

As mentioned above, this report is partly based on the input from natural resource management organizations and the local community. This input was obtained mostly through interviews with individuals with local knowledge and experience (Appendix A). For this report WTI relied on this information source where data obtained through actual measurements in the field were not available; in addition, the information obtained through interviews was used to supplement data obtained through measurements in the field.

When researchers attempt to address a real world problem, it is important to make use of all available data, including data obtained through interviews with individuals with local knowledge and experience. However, this does not necessarily mean that data obtained from different information sources (e.g. measurements vs. statements) should always be valued equally when decisions are made. Therefore the two types of information sources are clearly noted throughout the report.

3. PREVIOUS AND ONGOING EFFORTS

3.1. Introduction

This chapter briefly discusses previous and ongoing activities relevant to animal-vehicle collisions and habitat connectivity in the Seeley-Swan Valley. The Seeley-Swan Valley has hosted a variety of ungulate studies, especially for white-tailed deer (*Odocoileus virginianus*), from the 1970's through the 1990's (e.g. Janke, 1977; Mundinger, 1978; Mundinger, 1979; Slott, 1979; Mundinger, 1981; Leach, 1982; Arno *et al.*, 1987; Leach & Edge, 1994; Baty, 1995). (This knowledge is used in Chapter 5 to investigate the potential effect of a variety of road-, traffic-, and landscape variables on the occurrence of white-tailed deer-vehicle collisions.) This chapter lists studies and efforts that either relate to MT 83 more directly or that provide recent findings with regard to habitat connectivity for selected species in the Seeley-Swan Valley. These studies and efforts are listed separately for the areas south and north of the Clearwater Divide. The "Clearwater Divide" is the division between the Clearwater River and Swan River watershed near Summit Lake (Figure 2-1).

3.2. South of Clearwater Divide (Seeley Lake Area)

Two sections of MT 83 are proposed to be re-constructed over the coming years: 1) from Clearwater junction (junction with Montana Highway 200) to Seeley Lake and 2) from Seeley lake to the Clearwater Divide. A wildlife overpass and underpass will be constructed just south of Salmon Lake (Pers. com. Kerry Foresman, University of Montana; Pat Basting, MDT) and will be combined with limited stretches of wildlife fencing to guide animals toward these crossing structures. In addition, the road sections will have a wider right-of-way to increase the visibility of large animals about to cross the road and to reduce animal-vehicle collisions. Recently, forest management activities that may influence thermal cover and food availability for ungulates have been mapped in certain areas. A multi-organization working group has been formed to address animal-vehicle collisions and habitat connectivity between Seeley Lake and the Clearwater Divide (Pers. com. Pat Basting, MDT).

An overpass and an underpass will be constructed just south of Salmon Lake (Pers. com. Kerry Foresman, University of Montana; Pat Basting, MDT). The plans for this road section were finalized in the summer of 2004 (Pers. com. Pat Basting, MDT). In addition, the above-mentioned working group has identified five possible habitat linkage zones between Seeley Lake and the Clearwater Divide, and Northwest Connections has conducted snow tracking surveys in the winter of 2004-2005 to document wildlife crossings and identify the most intensively used areas (Pers. com. Pat Basting, MDT; Northwest Connections, unpublished data). The working group also addresses stream crossings, especially for bull trout (*Salvelinus confluentus*). Separate studies on fish passage and the potential barrier effect of culverts for fish species were conducted by Burford (2005) and Cahoon *et al.* (2005).

While these previous and on-going efforts provide very valuable information, there are currently no data available that identify high risk zones for animal-vehicle collisions along the entire transportation corridor in the Seeley-Swan valley. The same applies to zones that are important for habitat connectivity for selected species.

3.3. North of Clearwater Divide (Swan Valley)

No specific analyses have been done to identify high-risk zones for animal-vehicle collisions north of the Clearwater Divide, with the exception of the mapping of accident and high frequency crossing zones based on observations from the public by Northwest Connections (Pers. com. Melanie Parker, Northwest Connections). To promote grizzly bear (*Ursus arctos*) crossings, not all trees in the right-of-way were removed in certain road sections (Table 3.1). Trees were only removed in the zone from construction limit to construction limit or from clear zone to clear zone, whichever one was greater (Montana Department of Transportation, 1998; Pers. com. Breta Duncan, MDT). However, the efficacy of this effort has not been monitored (Pers. com. Pat Basting, MDT).

Table 3-1: Road sections with clearing limits along MT 83 (Montana Department of Transportation, 1998).

Stations and segments	Approximate Reference posts (RP) (Pers. com. Breta Duncan, MDT)
Sta. 1084+77 Segment 2 - Sta. 1141+00 Segment 2	49.1-50.3
Sta. 1283+22 Segment 1 - Sta. 977+80 Segment 2	52.7-54.2
Sta. 719+00 Segment 1 - Sta. 988+06 Segment 1	60.7-65.4

Previous grizzly bear studies have identified habitat linkage zones for grizzly bears (Pers. com. Chris Servheen; Pers. com. Tabitha Graves; Black, 2002) (Figure 3-1). In 1995, an interagency cooperative effort resulted in a land management plan that aims to protect and manage these linkage zones (Seeley Swan Pathfinder, 1996). Current grizzly bear research focuses on population size estimates, population trend, survival, and corridors (Kendall, unknown). In addition, the area hosts an ongoing Canada lynx (*Lynx Canadensis*) study (Keeping the Wild in the West, 2003).

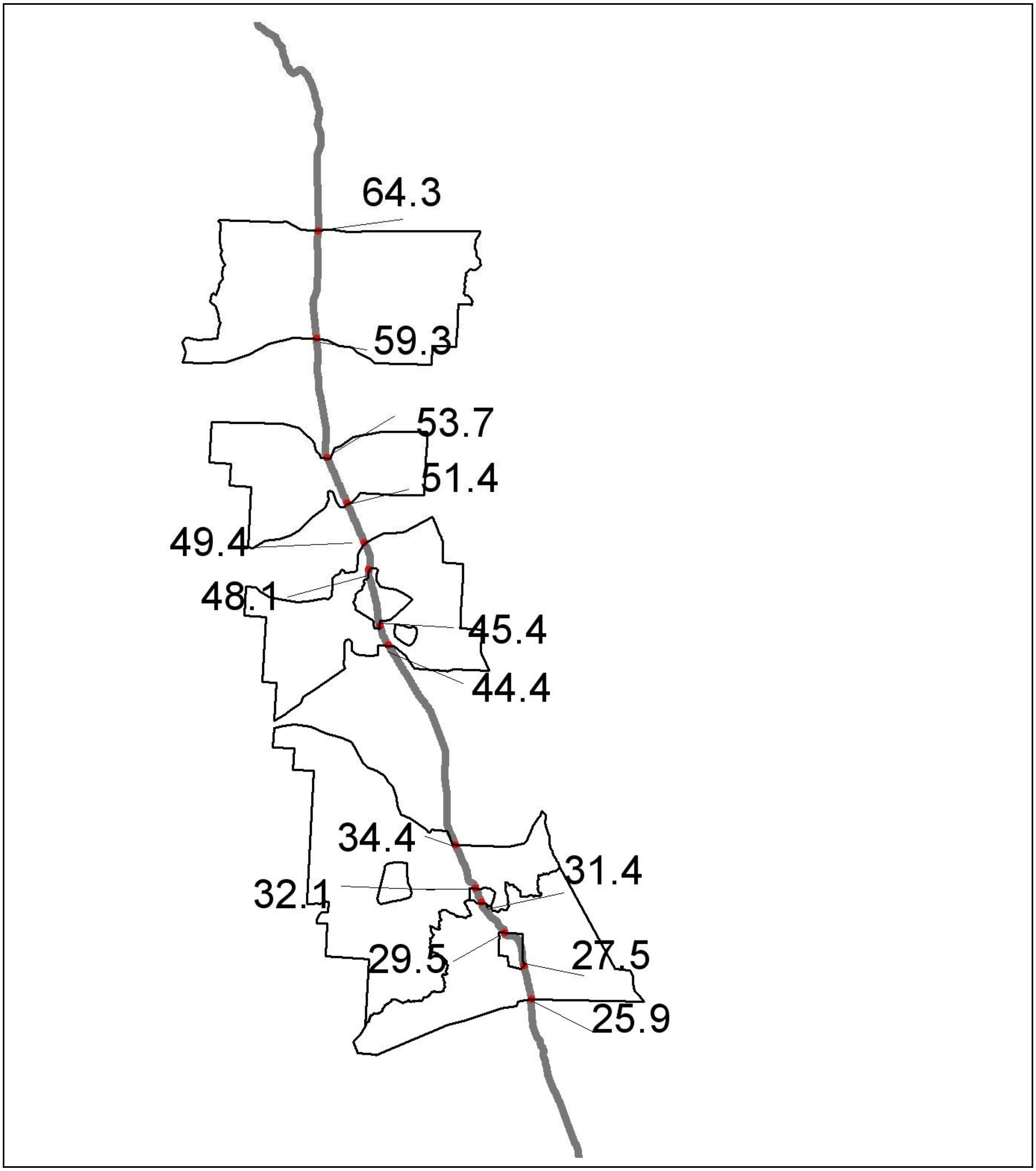


Figure 3-1: Road sections with reference posts (RP) where MT 83 intersects the grizzly bear management zones (Pers. com. Tabitha Graves)

4. HIGH-FREQUENCY ZONES FOR DEER-VEHICLE COLLISIONS

4.1. Introduction

Despite the previously mentioned efforts of Northwest Connections and the current efforts of the working group between Seeley Lake and the Clearwater Divide (see chapter 3), no transportation corridor wide detailed analyses of road-killed animals or animal-vehicle collision data are available for MT 83. For this study WTI analyzed animal-vehicle collision data provided by the Montana Department of Transportation (MDT) and Montana Highway Patrol (MHP). The main objective of this chapter is to identify and rank high-frequency zones for collisions with large animals, especially with white-tailed deer (*Odocoileus virginianus*).

4.2. Data Sources and Considerations

Animal-vehicle collision data were provided by MDT and MHP. The animal carcass and animal-vehicle collision data sets used in this study are summarized in Table 4-1. We evaluated these data sets based on the following criteria:

- Search and reporting effort
- Species reported
- Spatial accuracy

Table 4-1: Animal carcass and animal-vehicle collision data sets used for this study.

Source	Reference posts (section name)	Period	Resolution (mi (m))	Comments
MDT	0.0-47.8 (south)	1 Jan ‘98 – 31 Dec ‘03	0.1 (160.9)	Standard MDT format*1
MDT	47.8-80.0 (central)	1 Jan ‘02 – 31 Dec ’03	1.0 (1609)	Only “deer” species
MDT	80.0-91.1 (north)	1 Jan ‘98 – 31 Dec ‘03	0.1 (160.9)	Standard MDT format*1
MHP	0.0-91.1 (entire route)	1 Jan ’90 – 31 Dec ‘03	0.1 (160.9)	Only “wild animal”

*1: See appendix B for standard MDT format

4.2.1. Search and Reporting Effort

4.2.1.1. Southern Section (MDT)

MDT maintenance personnel monitors the southern section (Reference Post (RP) 0.0-47.8) twice a week in late spring, summer, and fall, specifically to collect and record animal carcasses and to remove other hazards on or near the road (Pers. com. Bruce Friede, MDT, see Appendix A: Contact Details of Interviewed Individuals). The monitoring takes place in the morning hours on Mondays and Fridays. On other days animal carcasses are reported when encountered, but this search and reporting effort only relates to the road section that happens to be driven. Only carcasses that lie on the road or that lie within 20 ft (6.1 m) from the edge of the pavement in the right-of-way are removed and reported. If a carcass is not a safety hazard and/or is not highly visible close to the road, the carcass is not removed or reported. However, if the sight distance is reduced, e.g. because of tall grass-herb vegetation or thick snow cover, not all carcasses close to the road are seen. During winter MDT maintenance personnel monitors the road section for animal carcasses and other hazards on or near the road every day. Carcasses reported to MDT by phone are promptly removed and reported. There was no substantial fluctuation in search and reporting effort over the time period covered by this data (Pers. com. Bruce Friede, MDT, Appendix A: Contact Details of Interviewed Individuals). Mowing is thought to reduce the number of collisions, perhaps through increased sight distance for drivers. The width of the mowed strip in the right-of-way is usually about 16 ft (4.9 m) on either side of the road. Bruce Friede estimates that about 80% of all (deer (*Odocoileus sp.*)) carcasses that are seen are actually removed and reported. Based on skid marks of car tires and debris, Bruce Friede also estimates that 30-40% of the deer that are hit are not reported because the carcass has been removed by others (e.g. Montana Highway Patrol, County Sheriff, Montana Fish, Wildlife & Parks, Jay Kolbe for Canada lynx (*Lynx canadensis*) study, Ken Wolff for Northern Rockies Raptor Center, other individuals, see Appendix A) or because the animal runs away from the road with unknown injuries. The location of the Reference Posts (RP) along the road section has not changed, at least not since 1998. The number of deer warning signs was increased in winter, but this is thought to have had little effect in reducing the number of animal-vehicle collisions.

4.2.1.2. Central Section (MDT)

MDT maintenance personnel monitors the central section (Reference Post (RP) 47.8-80.0) once a week in late spring, summer, and fall, specifically to collect and record animal carcasses and to remove other hazards on or near the road (Pers. com. Chuck McCleod, MDT, Appendix A). The monitoring takes place in the morning hours on Mondays. Only carcasses that lie on the road or that lie (visibly) in the right-of-way are removed and reported. During winter MDT maintenance personnel monitors the road section for animal carcasses and other hazards on or near the road every day. Carcasses reported to MDT by phone are promptly removed and reported. There was no substantial fluctuation in search and reporting effort over the years studied (Pers. com. Chuck McCleod, MDT, (Appendix A: Contact Details of Interviewed Individuals).

However, traffic intensity has increased, especially since 1991. Chuck McCleod estimates that about 80% of all (deer) carcasses that are seen are actually removed and reported. He also estimates that perhaps a third of the deer that are hit are not reported because the carcass is not a safety hazard and is not highly visible, because the carcass has been removed by others (e.g. Montana Highway Patrol, County Sheriff, Montana Fish, Wildlife & Parks, Jay Kolbe for Canada lynx study, Ken Wolff for Northern Rockies Raptor Center, other individuals, see Appendix A: Contact Details of Interviewed Individuals) or because the animal runs away from the road with unknown injuries. The location of the Reference Posts (RP) along the road section has not changed, at least not since 1998. Chuck McCleod perceives the areas between RP 48 and 67 as the highest frequency zones for animal-vehicle collisions in the central section. The Swan River and adjacent wet lands seem to be an attractant to white-tailed deer, and they cross the road frequently in this road section (see also Leach & Edge, 1994).

4.2.1.3. Northern Section (MDT)

MDT maintenance personnel monitors the northern section (Reference Post (RP) 80.0-91.1) twice a week in summer, specifically to collect and record animal carcasses and to remove other hazards on or near the road (Pers. com. Bert Johnson, MDT, Appendix A: Contact Details of Interviewed Individuals). The monitoring takes place in the morning hours on Mondays and Fridays. On other days animal carcasses are reported when encountered, but this search and reporting effort only relates to the road section that happens to be driven. Only carcasses that lie on the road or that lie (visibly) in the right-of-way are removed and reported. If a carcass is not a safety hazard and/or not highly visible close to the road, the carcass is not removed or reported. During winter (mid-October through 1 April) MDT maintenance personnel monitors the road section for animal carcasses and other hazards on or near the road every day. Carcasses reported to MDT by phone are promptly removed and reported. The width of the mowed strip in the right-of-way is usually about 12 ft (3.7 m) on either side of the road. Bert Johnson estimates that about 80% of all (deer) carcasses that are seen are actually removed and reported. Based on skid marks of car tires and debris he also estimates that 30% of the deer that are hit are not reported because the carcass has been removed by others (e.g. Montana Highway Patrol, County Sheriff, Montana Fish, Wildlife & Parks, Jay Kolbe for Canada lynx (*Lynx Canadensis*) study, Ken Wolff for Northern Rockies Raptor Center, other individuals, see Appendix A: Contact Details of Interviewed Individuals) or because the animal runs away from the road with unknown injuries. The location of the Reference Posts (RP) along the road section has not changed, at least not since 1998. The number of deer warning signs was increased in winter, but this is thought to have had little effect on reducing the number of animal-vehicle collisions. Bert Johnson perceives the areas between RP 85 and 90, especially between 85 and 86, where there is cover on both sides of the road, as the highest frequency zones for animal-vehicle collisions in the northern section.

4.2.1.4. Entire Route (MHP)

Some collisions with wild animals are reported to law enforcement agencies after which the Montana Highway Patrol or other law enforcement officers respond and visit the site of the reported accident (Pers. com. Pierre Jomini, MDT). If applicable a report of the accident is filed.

4.2.1.5. Monitoring Data vs. Incidental Observations

For this study it was important to determine whether the animal carcass data (MDT) and animal-vehicle collision data (MHP) were based on a consistent search and reporting effort (“monitoring”) for individual road sections rather than “incidental observations”. However, the study did not depend on the monitoring data to include all, or nearly all, animal carcasses or animal vehicle collision reports, as it was more important that data sets had consistent search and reporting efforts.

The three MDT data sets (southern, central and northern section) were mostly based on a search and reporting effort that was similar within each of the three road sections and can therefore be considered “monitoring data”. However, the search and reporting effort did differ between the three road sections (frequency of checks, potential observer effect). The data sets for the three sections also contained an unknown number of “incidental observations”, especially in late spring, summer and fall as the one or two searches per week were supplemented with incidental observations. However, the majority of the reported carcasses were found in winter (see “results” in this chapter) which indicates that the “pollution” of the MDT data sets with incidental observations was relatively limited. The MDT data sets had strong differences in search and reporting effort between seasons; the monitoring efforts were much more intense in winter than in late spring, summer or fall. If the data for the large animals, i.e. mostly white-tailed deer, show strong spatial differences between their summer and winter habitat along the road corridor, the relatively low search effort in summer could result in an underestimation of the presence and length of high frequency kill zones for the summer months. WTI also tested whether to account for these seasonal differences in monitoring effort and potential seasonal differences in the location of white-tailed deer-vehicle collisions (see analyses).

The MHP data set was based on accidents that were reported to law enforcement agencies. Therefore the search and reporting effort was dependant on drivers; it was not controlled by the agencies. However, unless people were more likely to call in a collision on certain road sections than on other road sections, the MHP data set the data can be considered monitoring data as well.

4.2.2. Species Reported

The MDT data sets for the southern (RP 0.0-47.8) and northern section (RP 80.0-91.1) contained relatively detailed data (including species name) for the same observation period (Table 4-1 and Appendix B: MDT's Animal-Carcass Parameters). Data was combined from these two sections to identify the most frequently reported road-killed animal species along MT 83 and to identify the species for which further analyses would be meaningful. There were 543 reported animal carcasses for the southern and northern section combined over a six year period: 1 January 1998 – 31 December 2003. The following species were reported: 513 (94.5%) white-tailed deer, 12 (2.2%) mule deer (*Odocoileus hemionus*), 5 (<1%) black bear (*Ursus americanus*), 4 (<1%) elk (*Cervus elaphus*), 2 (<1%) mountain lion (*Felis concolor*), 6 (1.1%) other wild animal species 1 coyote (*Canis latrans*), 5 skunk, most likely striped skunk (*Mephitis mephitis*)), and 1 (<1%) domestic animal species. Since almost 95% of the reported carcasses were white-tailed deer all further species specific and cluster analyses were done for this species only.

The MDT data set for the central section (RP 47.8-80.0) contained records for "deer" only and did not distinguish between white-tailed deer and mule deer. There were 78 reported deer carcasses for the central section over a two year period: 1 January 2002 – 31 December 2003.

The MHP data set for the entire transportation corridor (RP 0.0-91.1) related to collisions with wild animals, but did not list the species names. There were 233 reported animal-vehicle collisions for the entire transportation corridor over a 14 year period: 1 January 1990 – 31 December 2003.

4.2.3. Spatial Accuracy

The MDT data sets for the southern (RP 0.0-47.8) and northern section (RP 80.0-91.1), and the MHP data set (RP 0.0-91.1) contained white-tailed deer carcass and animal-vehicle collision records with a spatial resolution of 0.1 mile (160.9 m). The observers used the odometer of their vehicles to estimate the nearest 0.1 RP. However, of the 513 records for white-tailed deer in the MDT dataset, 12 records were only accurate to 1.0 mile (1,609 m) or did not have any spatial information. Because of their reduced or absent spatial accuracy these records were excluded from further spatial analyses (Table 4-2). The MDT data set for the central section (RP 47.8-80.0) contained deer carcass records with a spatial resolution of 1.0 mile (1,609 m). The MHP data set for the entire transportation corridor (RP 0.0-91.1) contained collision records with a spatial resolution of 0.1 mile (160.9 m).

Table 4-2 Summary statistics of white tailed deer carcasses and animal-vehicle collisions.

Data source and RP	Total	Mean	SD	Median	Min.	Max.
MDT 0.0-47.8*1 (south)	454	2.07	1.63	2	1	12
MDT 47.8-80.0*2 (central)	78	3.00	2.48	2	1	10
MDT 80.0-91.1*1 (north)	47	1.47	0.67	1	1	3
MHP 0.0-91.1*1 (entire route)	233	1.19	0.50	1	1	4

*1 for 0.1 mi units (160.9 m); *2 for 1.0 mi units (1609 m)

Total = total number of reported white-tailed deer or deer carcasses or reported accidents. Mean/Median = mean/median number of reported white-tailed deer or deer carcasses or reported accidents per 0.1 mi or 1.0 mi long road section, excluding 0.1 or 1.0 mi road units with zero observations. RP = Reference Pos.; SD = Standard deviation; Min. = lowest reported value; Max. = highest reported value.

4.3. Changes in the Traffic Volume, Deer Population Size, Road or Landscape

Major changes in the traffic volume, deer population size or changes to the road or landscape may result in an increase or decrease in the number of animal-vehicle collisions. Databases from MDT and natural resource management agencies were consulted with regard to potential changes in traffic volume and deer population size. In addition, MDT personnel, personnel from natural resource management agencies, and individuals with local knowledge and expertise were interviewed with regard to potential changes (see Appendix A: Contact Details of Interviewed Individuals).

Traffic volume on MT 83 has gradually increased between 1993 and 2003 (Figure 4-1). The summer months have the highest traffic volume (Figure 4-2).

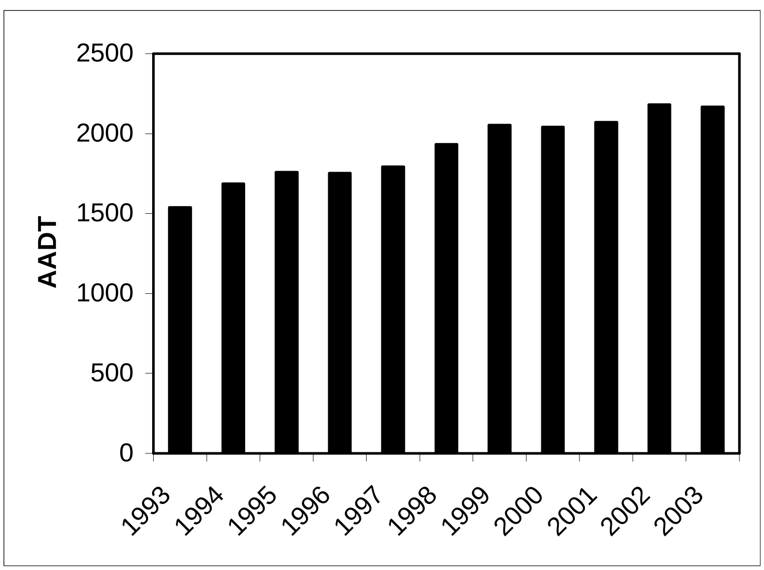


Figure 4-1 Annual Average Daily Traffic volume (AADT) for MT 83 (A-66, RP 0.8 near jct with MT 200) between 1993 and 2003.

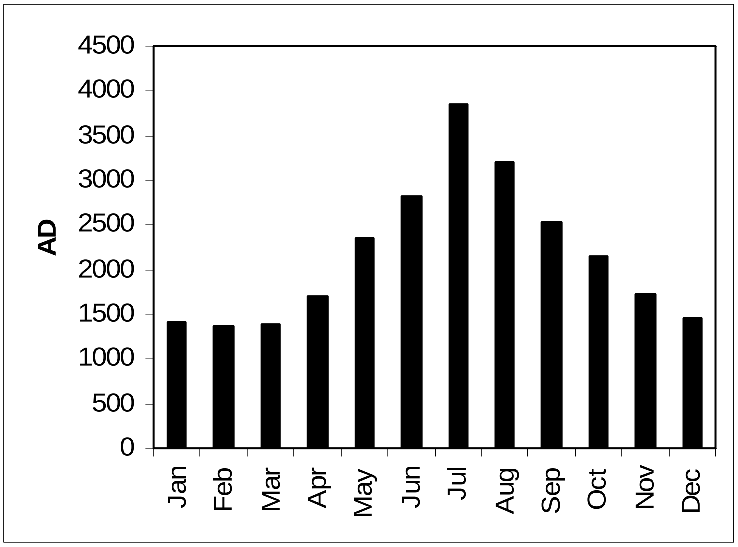


Figure 4-2 Average Daily Traffic volume (ADT) per month for MT 83 (A-66, RP 0.8 near jct with MT 200) for 2003.

Deer harvest numbers not only depend on deer population size but also on the number of hunting permits issued, the actual hunting effort, and hunting conditions. Therefore the deer harvest estimates may not accurately reflect changes in the deer population. Nevertheless, when the population size is high, more permits tend to be issued resulting in a greater number of deer harvested. Deer harvest estimates showed a strong increase between 1993 and 1996, both south (Figure 4-3) and north (Figure 4-4) of the Clearwater Divide. After a severe winter (1996-1997) deer harvest estimates were much lower, but have been increasing steadily since.

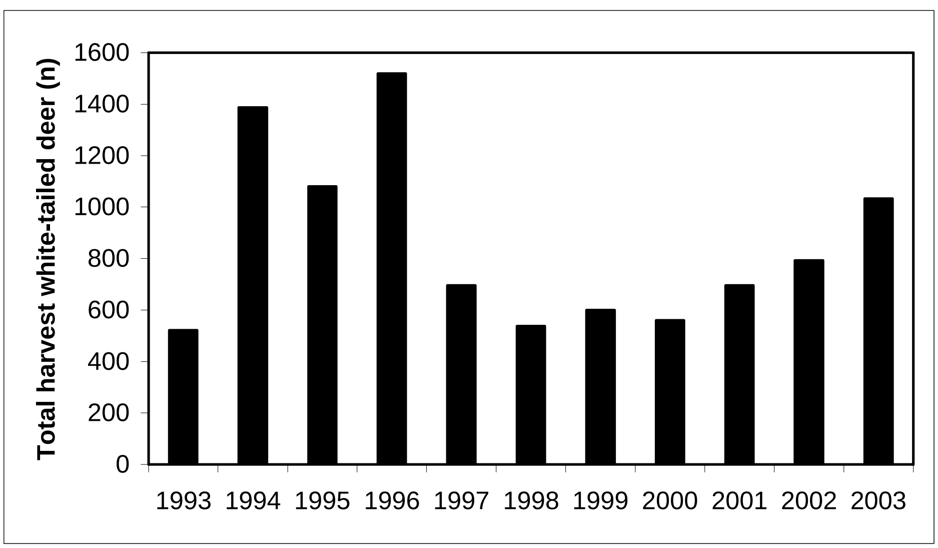


Figure 4-3. Total harvest estimate for white-tailed deer Hunting District 285 (Source: Mike Thompson, MT FWP, Appendix A).

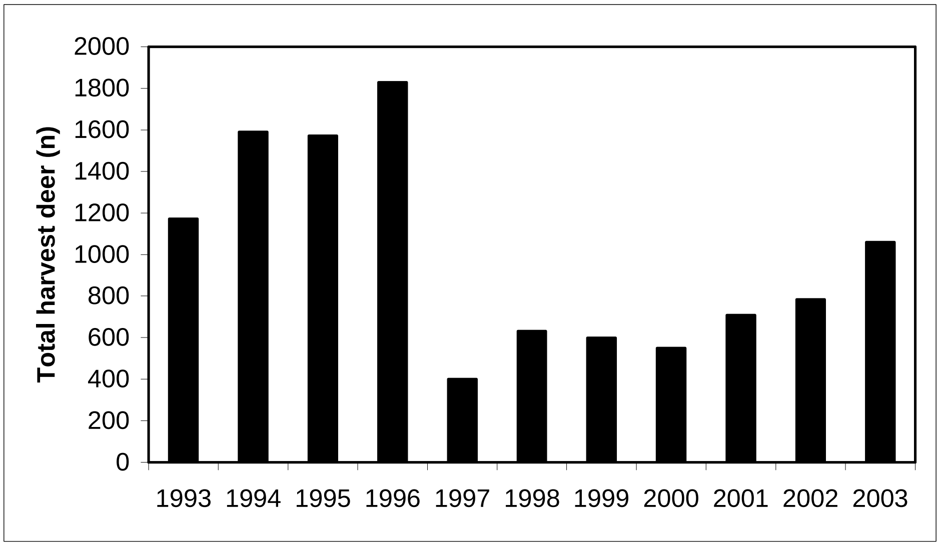


Figure 4-4. Total harvest estimate for deer (white-tailed and mule deer) Hunting District 130 (Source: Thomas Litchfield, MT FWP, Appendix A).

Since 1990 there have been four major road projects along MT 83 (Table 4-3). The road projects mostly resulted in a wider road surface, an increased width of the clear zone and wider mowing strips. Increased shoulder width and wider mowing strips are thought to lead to fewer animal-vehicle collisions (Pers. com. Bruce Friede, MDT, Appendix A: Contact Details of Interviewed Individuals), potentially as a result of increased sight distance for drivers. However, in selected areas cover was allowed to grow closer to the road to make MT 83 less of a barrier to grizzly bears (*Ursus arctos*). In addition, there have been substantial changes in land management, including more intensive forest management activities and subdividing, and some local individuals now feed the deer regularly (Table 4-4). The above conditions are thought to have resulted in an increase of the deer concentration or deer population along the road corridor and a partial loss of migratory behavior.

The Montana Department of Transportation (MDT) typically uses sodium chloride (NaCl) mixed in with sand (7-15 volume %) to de-ice the road surface of MT 83 (Williams, 2003; Pers. com. Bruce Friede, MDT, Appendix A: Contact Details of Interviewed Individuals). Cyanide (CN), an anti-caking substance, was also added to the sand, but this practice was abandoned 2-3 years ago (Pers. com. Bruce Friede, MDT, Appendix A: Contact Details of Interviewed Individuals). Currently, MDT also uses liquid magnesium chloride (MgCl), especially close to lakes and other water, as magnesium chloride is less environmentally damaging than sodium chloride (Williams, 2003; Pers. com. Bruce Friede, MDT, Appendix A: Contact Details of Interviewed Individuals). In addition, a substantial reduction in the use of chemicals can be obtained by applying liquid magnesium chloride as an anti-icing and pre-wetting agent as it is much more efficient than applying solid sodium chloride as a de-icer (Williams, 2003). Road salt can be an attractant to ungulates (e.g. Miller & Litvaitis, 1992); however, there are contrasting opinions as to how much the presence of road salt contributes to deer-vehicle collisions along MT 83 (Pers. com. Bruce Friede, MDT; Jay Kolbe, Appendix A: Contact Details of Interviewed Individuals).

It is unclear whether the changes in the road and landscape mentioned above resulted in a net increase or decrease in the number of animal-vehicle collision numbers since 1990. However, the changes do suggest that collision data from over a decade ago may be related to road and landscape conditions that are no longer present today.

Table 4-3. Major road projects along MT 83 since 1990 (Pers. com. Pierre Jomini, MDT).

Construction period	RP	Main activities	Additional activities
29 Jun ’92 – 16 Aug ‘93	23.1-31.5	Road widened from 24 ft to 28 ft to add 2 ft wide shoulders.	Roadway inslopes flattened from 2:1 to 4:1; Obstacles cleared from clear zone.
7 Sep ’94 – 15 Aug ‘96	31.5-47.8	Road widened from 24 ft to 28 ft to add 2 ft wide shoulders.	Pavement inslopes flattened from 3:1 to 6:1; Ditch inslopes flattened from 3:1 to 4:1 of 6:1; Narrower clear zone in grizzly bear linkage areas; Obstacles cleared from clear zone.
25 Mar ’96 – 22 Jul ‘98	47.8-60.9	Road widened from 24 ft to 28 ft to add 2 ft wide shoulders.	Pavement inslopes flattened from 3:1 to 4:1; Ditch inslopes flattened from 3:1 to 6:1; Clear zone on one side only in grizzly bear linkage areas; Obstacles cleared from clear zone.
3 Aug ’00- 5 Jul ‘01	13.1-14.7	Road widened from 24-26 ft to 48 ft to add a turn lane and wider shoulders.	Pavement and ditch inslopes flattened to 6:1; Obstacles cleared from clear zone.

Table 4-4. Other changes in the road, landscape or wildlife management since 1990. Note: non-road related changes were not initiated or conducted by MDT.

Area	Changes	Source (Appendix A)
South: Condon area	Trees moved back from edge pavement, wider mowing zone	Bruce Friede (MDT)
South: S. of Seeley Lake, ±RP 13	A golf course, an attractant to deer, was constructed.	Bruce Friede (MDT)
South: Lake Alva/Lake Inez area: around RP 38	Logging activities attracted deer (eat mosses off trees); Loss of thermal cover for animals; Change in migration patterns.	Bruce Friede (MDT)
Central: N. of RP 65	Vegetation was allowed to grow closer to the road in grizzly bear linkage areas.	Chuck McCleod (MDT)
Entire route	Clear cuts, removal of undergrowth, thinning, subdivisions, and deer feeding on private lands have changed cover, food (also for carnivores) and historical animal movement patterns.	Bill Bartlett, Anne Dahl, Bruce Friede, Glen Gray, Jay Haveman, Tom Parker, Ken Wolff
Entire route	Deer have benefited from human induced changes in the landscape and benefit from interactions with humans. They are now concentrated along MT 83, and in part are no longer migratory. Low predator numbers along the road, especially wolves, is also making this a shelter for deer.	Bud Moore, Tom Parker, Scott Tomson

4.4. Analyses

4.4.1. Analyses of Trends and Characteristics of White Tailed Deer Carcasses and Collisions with Wild Animals

The MDT data sets for the southern and northern section were combined and the MHP data set were analyzed for a potential increase or decrease in the number of white-tailed deer carcasses and the number of collisions with wild animals. The datasets were also analyzed for potential seasonal trends in numbers, and the sex and age of the white-tailed deer carcasses. Finally, the MHP data set was analyzed for potential trends in the number of collisions with wild animals over the different days of the week, the hour of the day and the number and location of human injuries and human fatalities.

The data for the central section were not analyzed for trends and characteristics as the data related to only two years, did not distinguish between white-tailed and mule deer, did not contain details on the sex or age of the carcasses, and the data were grouped for multiple months and different time periods for 2002 and 2003.

4.4.2. Cluster Analyses

Areas with a relatively high number of white-tailed deer or deer carcasses and collisions with wild animals are referred to as “clusters”. The spatial units for the analyses that identified such clusters were 0.1 or 1.0 mile, depending on the spatial resolution of the original data set. However, observers typically make mistakes when logging the location of a carcass or accident (Clevenger *et al.*, 2002). For the cluster analyses the effect of such potential location errors was reduced by taking the sum of the values (“deer value”) for the unit concerned and its two neighboring units. Thus the “deer value” for each spatial unit (0.1 or 1.0 mi) related to the number of white-tailed deer or deer carcasses or reported accidents with wild animals in a 0.3 or 3.0 mi road length section (Table 4-5).

Table 4-5. Summary statistics for the "deer value" for the four datasets.

Data source and RP	Total	Mean	SD	Median	Min.	Max.
MDT 0.0-47.8*1 (South)	1,362	3.80	2.90	3	1	20
MDT 47.8-80.0*2 (Central)	218	6.81	5.70	5	1	23
MDT 80.0-91.1*1 (North)	139	2.17	1.24	2	1	6
MHP 0.0-91.1*1 (Entire route)	699	1.56	0.89	1	1	6

*1 for 0.1 mi units (160.9 m); *2 per 1.0 mi units (1609 m)

Total = Total of all “deer values”. Mean/Median: mean/median “deer value” per 0.1 mi or 1.0 mi long road section, excluding 0.1 or 1.0 mi road units with zero observations (“deer value” = 0). RP = Reference Post; SD = Standard deviation; Min. = lowest “deer value”; Max. = highest “deer value”.

For this study we distinguished between cluster categories for the “deer values”. The cut-off levels for these categories were determined using the following procedure:

- “Outliers” were identified within each of the four data sets and excluded from the procedure that determined the cut-off levels between cluster categories. Outliers were values that fell outside of the range “mean ± 2*SD”. Zero values were also excluded from the procedure as they formed their own cluster category (“absent”).
- Within each of the four data sets the 20, 40, 60 and 80% percentiles were identified.
- These percentiles formed the cut-off levels between the different categories (Table 4-6).

Table 4-6. Cut-off levels for the cluster categories (based on percentiles for "deer value").

Data source and RP	Absent (0%)	Very low (0-20%)	Low (20-40%)	Medium (40-60%)	High (60-80%)	Very high (80-100%)
MDT 0.0-47.8*1 (South)	0	1	1	2	3-4	5-20
MDT 47.8-80.0*2 (Central)	0	1	2-3	4-5	6-7	8-23
MDT 80.0-91.1*1 (North)	0	1	1	2	2	3-6
MHP 0.0-91.1*1 (Entire route)	0	1	1	1	1	2-6

*1 for 0.1 mi units (160.9 m); *2 per 1.0 mi units (1609 m)

Each spatial unit was assigned the lowest possible cluster category. For example, for the MDT data set from the southern section, a spatial unit (0.1 mi) with a "deer value" of 1 was classified as "very low" rather than "low".

The range of "deer values" was relatively narrow for the MDT data set for the northern section (0-6) and for the MHP data set (0-6). This resulted in a limited number of cluster categories for these data sets with very small differences between the cluster categories. For example, spatial units from the MHP data set with a deer value of 1 were classified as "very low" while deer values of 2 and higher resulted in a "very high" classification.

Note: the cluster categories relate to the relative occurrence of white-tailed deer or deer carcasses and collisions with wild animals within each individual data set and corresponding road section. Since the "deer values" and cluster categories do not relate to a fixed norm they can be compared across the four data sets and the different road sections.

Road sections that had "very high" deer values were listed in a separate table (see Results). If adjacent spatial units had a "high" deer value these adjacent spatial units were included in the road sections with "very high" deer values.

A test was conducted to determine the need to account for seasonal differences in monitoring effort and potential seasonal differences in the location of white-tailed deer-vehicle collisions (see monitoring data vs. incidental observations) (Table 4-7). The summer and winter periods coincide with seasonal changes in MDT's search and reporting effort (see section on search and reporting effort). White-tailed deer carcasses were found in similar proportions in- and outside high frequency kill zones in winter and in summer (P=0.172, chi^2 test (Pearson statistic)) (Table 4-7). This indicates that by grouping the data for winter and summer, the presence and length of high frequency collision zones in summer is unlikely to be underestimated. Based on this test no distinction was made between seasons for the purpose of this analysis.

Table 4-7. The number of reported white-tailed deer carcasses by MDT (southern and northern section combined) in- and outside of high frequency kill zones (see results) in winter and summer between 1998 and 2003.

Season	Inside high frequency kill zone (n (%))	Outside high frequency kill zone (n (%))	Total (n (%))
Winter (15 Oct – 31 Mar)	225 (73.05)	83 (26.95)	308 (100)
Summer (1 Apr – 14 Oct)	130 (67.36)	63 (32.64)	193 (100)
Total	355 (70.86)	146 (29.14)	501 (100)

4.5. Results

4.5.1. Trends and Characteristics of White Tailed Deer Carcasses and Collisions with Wild Animals

The number of white-tailed deer carcasses reported by MDT and the number of collisions with wild animals reported by MHP varied greatly between years (Figure 4-5, Figure 4-6). The number of white-tailed deer carcasses does not show a consistent increase or decrease between 1998 and 2003 (Figure 4-5). However, the number of accidents with wild animals reported by MHP was relatively low between 1990 and 1994, followed by a rather consistent increase between 1993 and 2000 (Figure 4-6). The number of reported accidents then stabilized at slightly lower level (2001-2003).

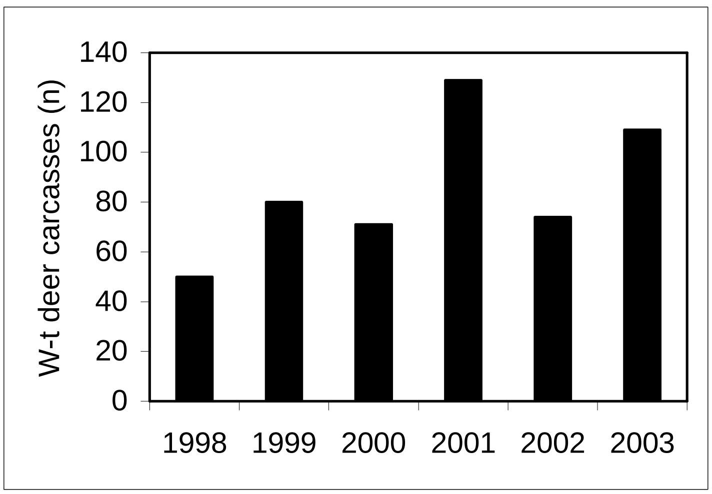


Figure 4-5 The number of white-tailed deer carcasses reported by MDT (southern (RP 0.0-47.8) and northern section (RP 80.0-91.1) combined) between 1998 and 2003.

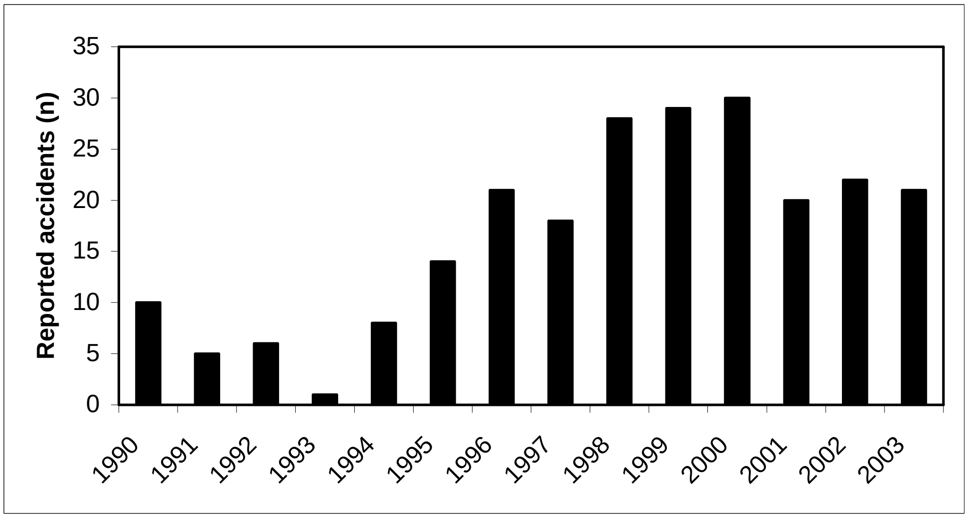


Figure 4-6 The number of collisions with wild animals reported by law enforcement agencies for the entire transportation corridor (RP 0.0-91.1) between 1990 and 2003.

The total number of deer carcasses (white-tailed and mule deer combined) reported by MDT in 2002 and 2003 combined was 265; 133 per year. MDT maintenance personnel estimated that they only report about 80% of the deer carcasses that they see. Assuming that this is correct, the total number of deer carcasses seen by MDT maintenance personnel may be 166 per year. Based on skid marks and debris MDT maintenance personnel also estimates that about 30-40% of all the deer that are hit are removed by others or run off injured. Assuming that this is correct, the average number of deer hit along MT 83 may be 237-276 per year.

Most of the white-tailed deer carcasses in the southern and northern section were reported in the winter months (October through April) and relatively few during the summer months (May through September) (Figure 4-7). Far more female white-tailed deer were killed than male (females 58.9%; males 11.7%, n =513). The central section showed a similar pattern: females 51.3%; males 7.7%, n =78. The number of reported accidents with wild animals was highest during the summer and fall (June through October) (Figure 4-8). Far fewer accidents were reported in winter and spring (November through May).

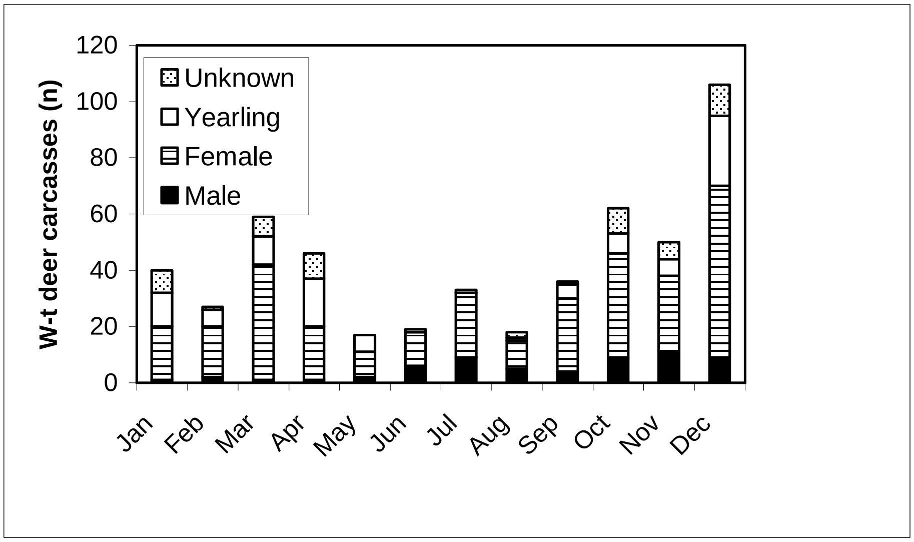


Figure 4-7 Seasonal distribution of white-tailed deer carcasses reported by MDT (southern (RP 0.0-47.8) and northern section (RP 80.0-91.1) combined) between 1998 and 2003.

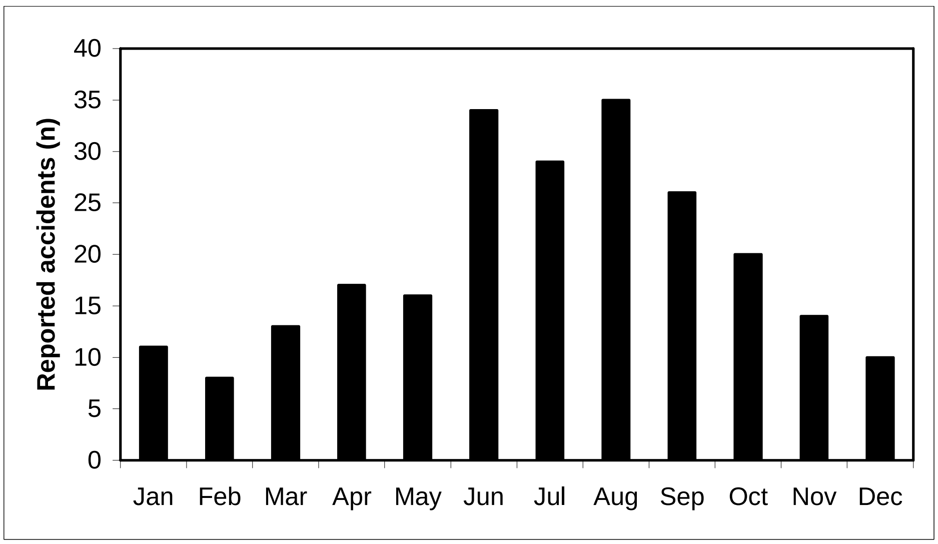


Figure 4-8 Seasonal distribution of reported collisions with wild animals by law enforcement agencies for the entire transportation corridor (RP 0.0-91.1) between 1990 and 2003.

The MHP data set did not show a consistent difference in the number of reported collisions with wild animals between weekdays and weekend days (Figure 4-9). However, most of the collisions occurred in the late afternoon and evening (17:00-23:00) and early morning (7:00-8:00) (Figure 4-10). The number and location of human injuries and fatalities is listed in Table 4-8. There were 40 human injuries and 1 human fatality out of the 233 reported collisions with wild animals. Table 4-9 lists the road sections for which human injuries and human fatalities were reported less than five miles (8.01 km) apart.

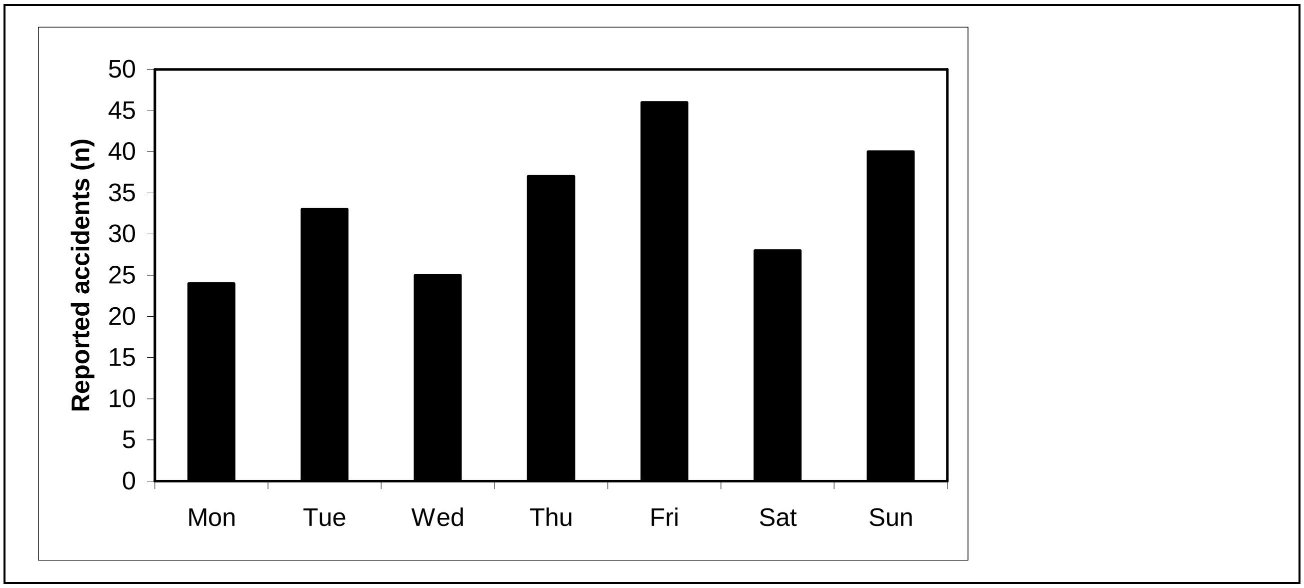


Figure 4-9 The distribution of collisions with wild animals reported by law enforcement agencies for the entire transportation corridor (RP 0.0-91.1) for the days of the week between 1990 and 2003.

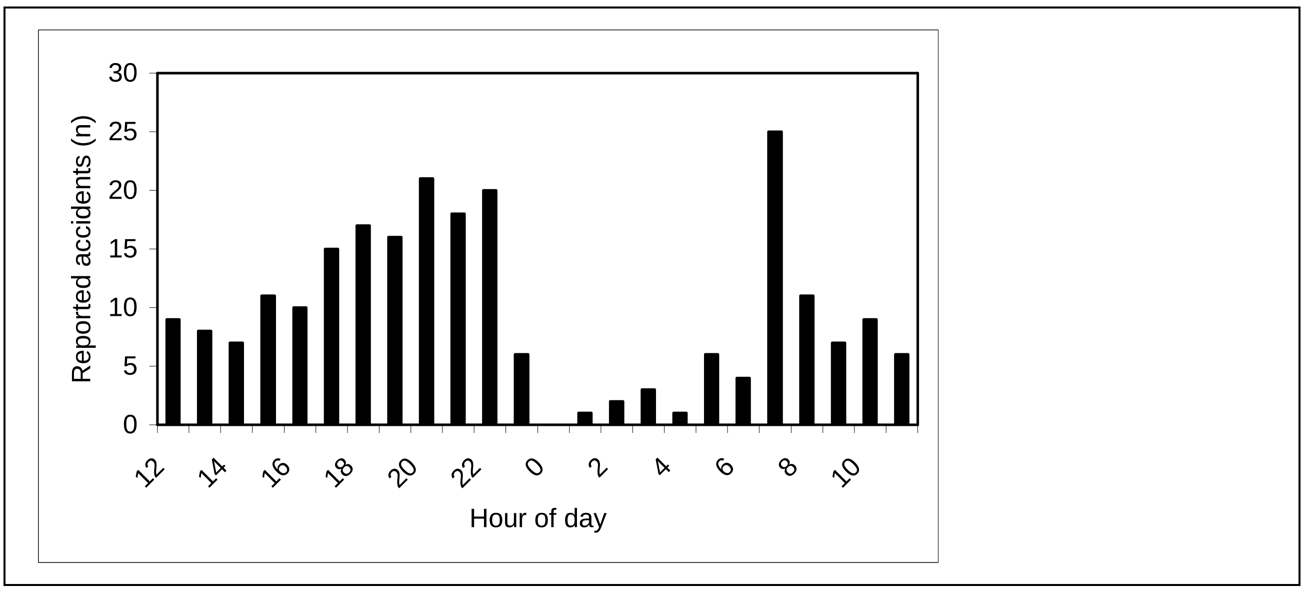


Figure 4-10 The distribution of collisions with wild animals reported by law enforcement agencies for the entire transportation corridor (RP 0.0-91.1) for the hour of day between 1990 and 2003.

Table 4-8 Location of reported human injuries and human fatalities as a result of a collision with a wild animal.

RP	Injuries	Fatalities		RP	Injuries	Fatalities
11.3	1			45.1	2[*1]	
11.7	1			47.1	1	
12.5	1			47.9	1	
14.7	1			50.5	1	
17.0	2[*1]			54.0	1	
18.1	1			56.9	2[*1]	
26.1	1			57.9	1	
27.0	1			58.2	1	
33.1	1			60.5	2[*1]	
35.0	1			60.8	1	
36.0	1			70.3	1	
36.2	1			80.0	4[*3]	
38.5	1[*2]	1[*2]		81.4	1	
40.5	1			83.3	1	
42.0	2			83.5	1	
42.4	1			84.7	1	

[*1] Both people were injured in the same accident; [*2] Two separate accidents;
[*3] Four people were injured in two separate accidents (2 injuries for each accident)

Table 4-9 Road sections with human injuries and fatalities (less than 5 mi apart).

RP		RP
11.3-18.1		70.3
26.1-27.0		80.0-84.7
33.1-60.8		

4.5.2. Cluster Analyses

The number of reported white-tailed deer and "deer" carcasses (MDT datasets) were plotted on maps for the three road sections (Figure 4-11, Figure 4-12, Figure 4-13).

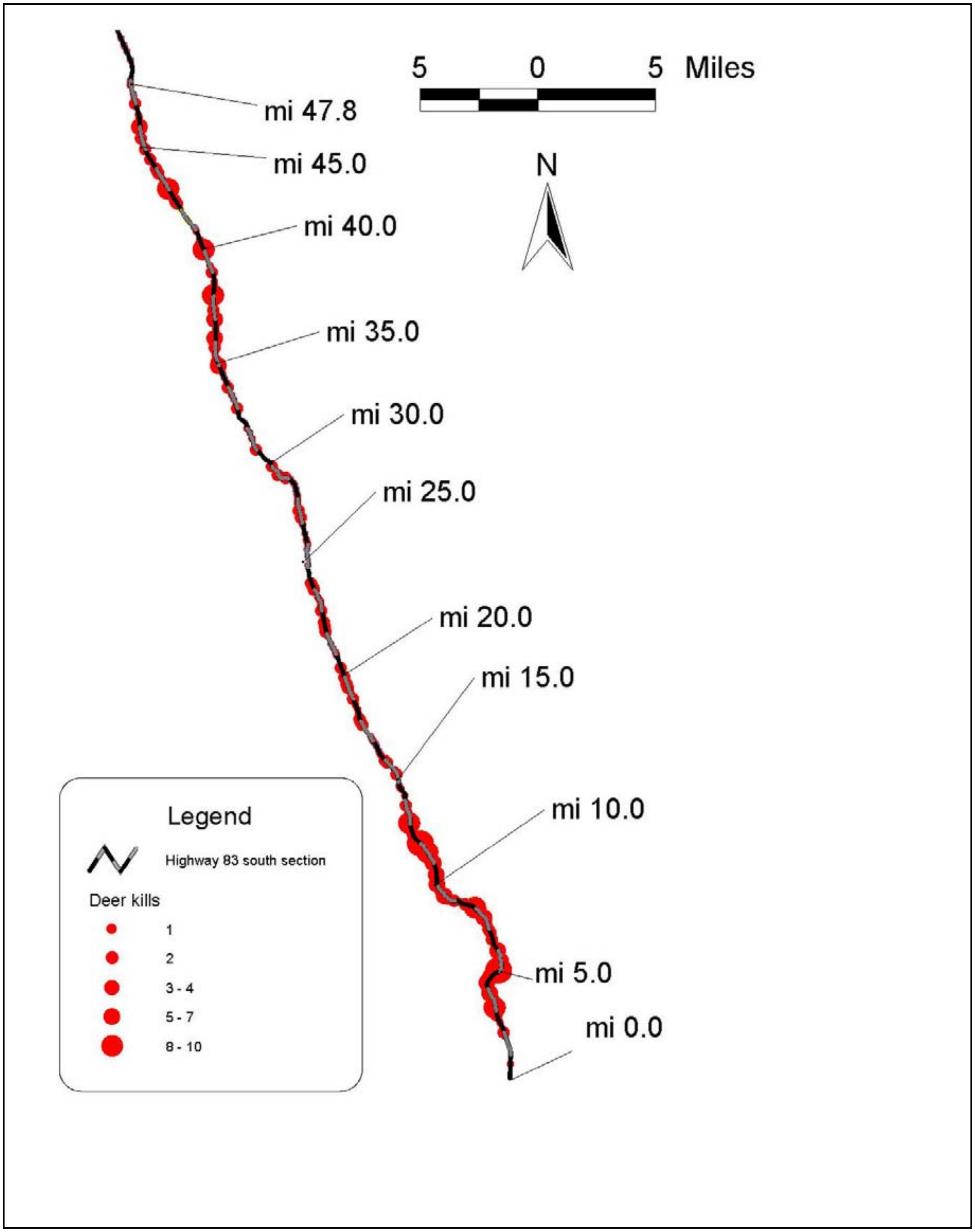


Figure 4-11 The number of reported white-tailed deer carcasses for each 0.1 mile unit for the southern section (RP 0.0-47.8, MDT data set).

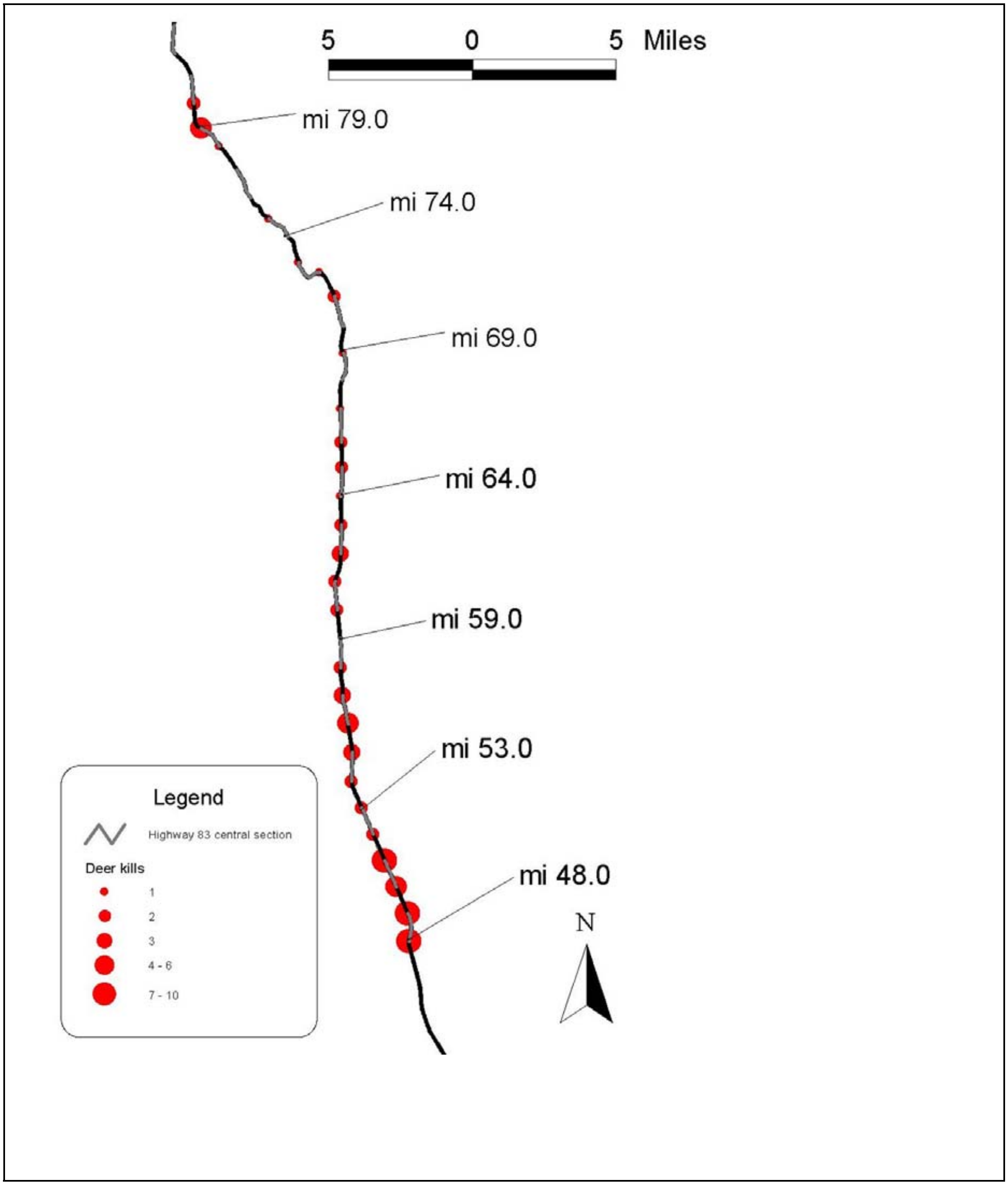


Figure 4-12 The number of reported deer (white-tailed deer and mule deer) carcasses for each 1.0 mi unit for the central section (RP 48.0-80.0, MDT data set).

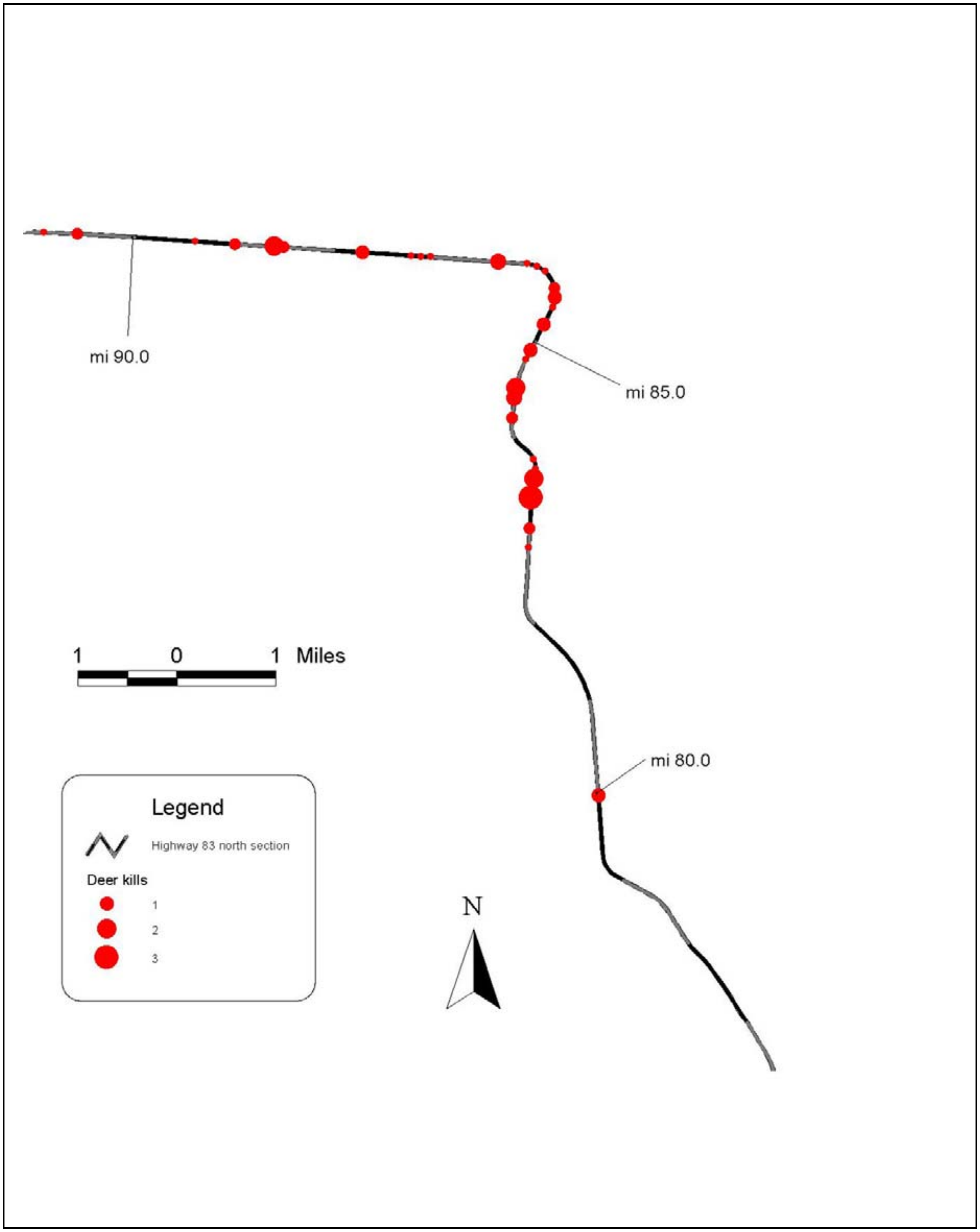


Figure 4-13 The number of reported deer carcasses for each 0.1 mi unit for the northern section (RP 80.0-91.1, MDT data set).

The "deer values" for each spatial unit for each of the four data sets are presented in Figure 4-14, Figure 4-15, Figure 4-16, and Figure 4-17. Appendix C contains the original carcass and collision numbers as well as the deer values and assigned cluster categories. While white-tailed deer or deer carcasses and collisions with wild animals occur along most of the transportation corridor, there are certain road sections that have a higher concentration than others. These road sections are listed in Table 4-10. The table also shows the similarities and differences between the MDT and MHP datasets.

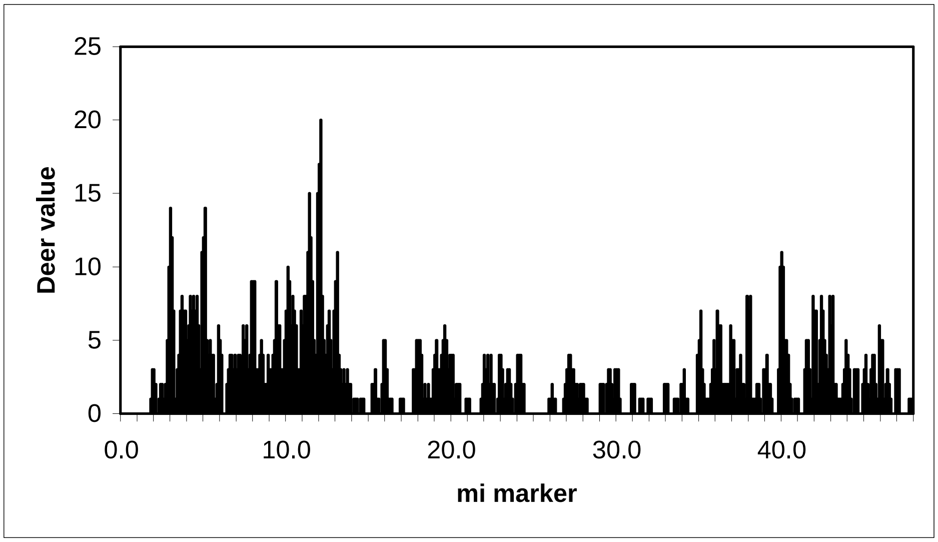


Figure 4-14 The deer values for each 0.1 mi unit for the southern section (MDT data set).

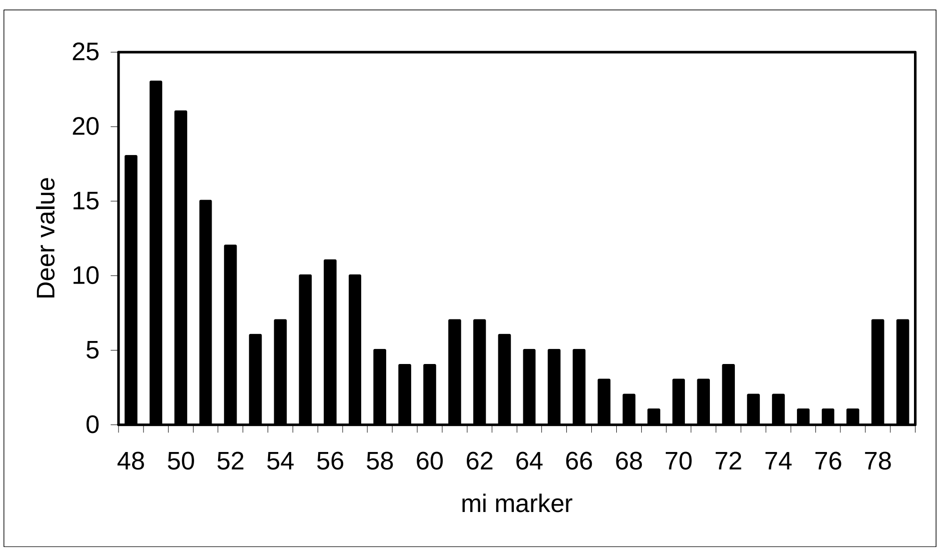


Figure 4-15 The deer values for each 1.0 mi unit for the central section (MDT data set).

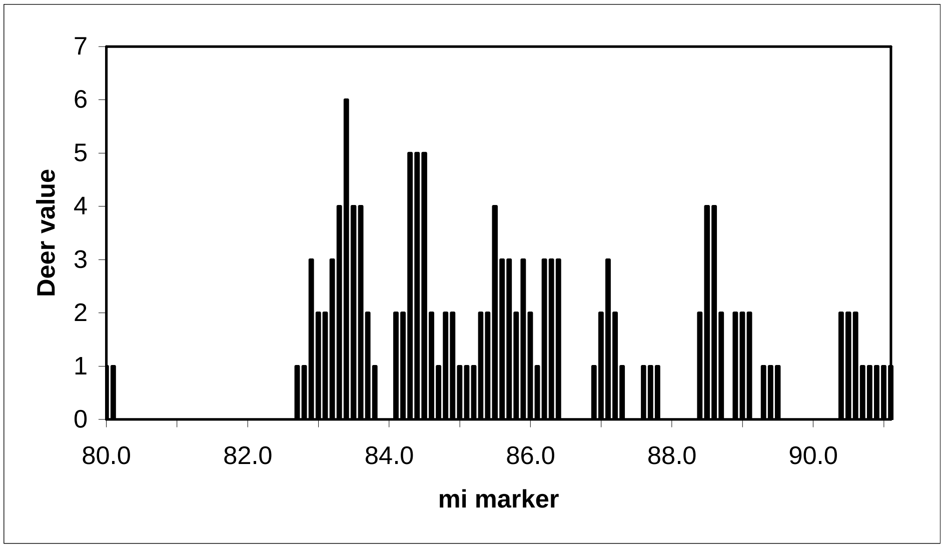


Figure 4-16 The deer values for each 0.1 mi unit for the northern section (MDT data set).

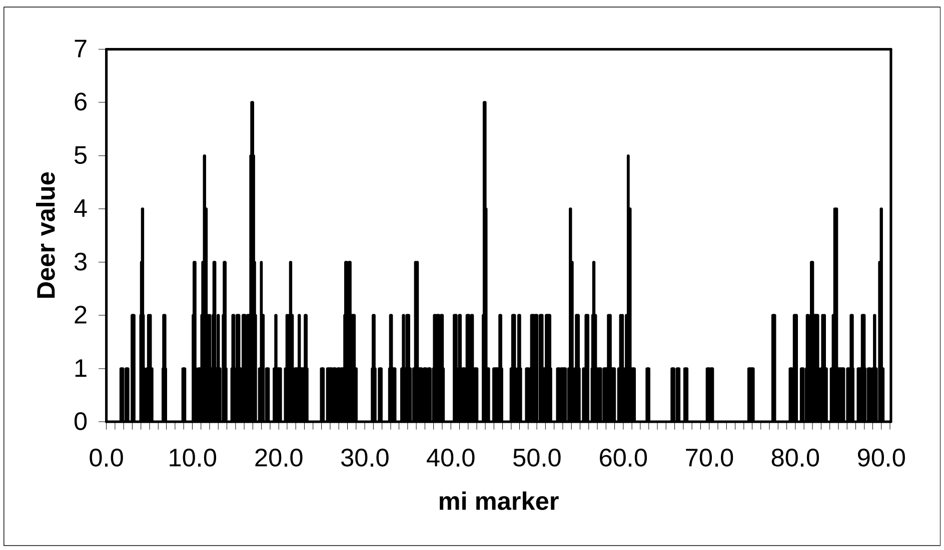


Figure 4-17 The deer values for each 0.1 mi unit for the entire transportation corridor (MHP data set).

Table 4-10 Areas with a 'very high' deer value for the MDT and MHP data sets (see Appendix C).

Clusters MDT (RP)	Clusters MHP (RP)		Clusters MDT (RP)	Clusters MHP (RP)
2.8-3.2	3.0-3.2		41.9-42.1	41.9-42.1
3.4-5.6	4.0-4.3, 4.9, 5.1		42.3-43.1	42.4-42.5
5.9-6.1			43.8-44.1	43.8-44.1
6.5-8.6	6.7-6.8			45.7-45.8
8.9-13.3	10.1-10.3, 11.1-11.6, 11.8, 12.0, 12.4-12.6, 13.0		45.9-46.1	
	13.6-13.8			47.2-47.4
	14.7-14.8			47.9-48.0
	15.2-15.4		48.0-57.9	49.4-49.6, 49.8-50.0, 50.4-50.6, 51.1-51.5, 53.9-54.1, 54.6-54.8, 55.7-55.9, 56.5-56.8
15.9-16.1	15.9-16.1			58.3
	16.4-17.3			58.5
17.7-18.2	18.0-18.2			59.7
18.9-20.1	19.7			59.9
	21.0			60.4-60.8
	21.2			77.4-77.6
	21.4-21.6			79.9-80.1
	22.4			81.4-81.5
	13.1-23.2			81.8-82.6
	27.7-28.8		82.9	
	31.0-31.1		83.2-83.6	83.2, 83.4
	33.0-33.1		84.3-84.5	84.4
	34.5			84.6-84.8
34.9-35.2	34.9-35.1		85.5-85.7	
35.8-36.3	35.9-36.1		85.9	
36.9-37.1			86.2-86.4	
37.9-38.1	38.1-38.2			86.5-86.6
	38.4-38.6		87.1	
	38.9-39.0			87.8-88.0
39.8-40.4	40.4-40.6		88.5-88.6	
	41.0-41.1			89.2
41.4-41.7				89.8-90.0

4.6. Discussion

The MDT data sets for the northern and southern section showed no consistent increase or decrease in the number of reported white-tailed deer carcasses between 1998 and 2003. However, the MHP data set suggests an increase in the number of accidents with wild animals between 1993 and 2000. This may reflect a true increase in the concentration or population size of wild animals along the transportation corridor, especially of white-tailed deer. This seems to be confirmed by a consistent increase in deer harvest estimates between 1993 and 1996. However, deer harvests were relatively low between 1997 and 2000. The increase in deer density or population size could have been caused by major changes in land use and land management and deer feeding along the transportation corridor. However, it is also possible that the increase in reported collisions with wild animals is at least partially caused by changes to the road and potential changes in vehicle speed. Finally, drivers may have become more likely to report the accident to law enforcement agencies, e.g. to document the accident for insurance purposes.

The average number of deer hit along MT 83 may be as high as 237-276 per year. However, this estimate is based on data for 2002 and 2003 only, and it is based on a series of assumptions and anecdotal estimates made by MDT maintenance personnel with local knowledge and experience. Other individuals with local knowledge and experience (Appendix A: Contact Details of Interviewed Individuals) estimate that not 30-40%, but perhaps 50% of the deer that are hit run off injured and die away from the road (Joe Lawrence, Appendix A: Contact Details of Interviewed Individuals). Carcass removal by other organizations and individuals may also be higher than estimated (Pers. com. Tabitha Graves, University of Montana). For example, Jay Kolbe (Appendix A: Contact Details of Interviewed Individuals) collects road kill for a Canada lynx study and has picked up at least 60 deer carcasses in a three month period (December-March). Joe Lawrence (Appendix A: Contact Details of Interviewed Individuals) estimates that perhaps as many as 1,000 deer per year are hit by traffic hit on MT 83. The purpose of the abovementioned estimates of the number of deer-vehicle collisions along MT 83 is to achieve the best possible insight in the number of deer that may be hit. The estimates should not be seen or treated as hard numbers. However, the estimates do show that the number of deer hit along MT 83 each year is probably several hundred, and that it is very unlikely that this number is less than 100 or more than 1000.

There seems to be a discrepancy between the seasonal distribution of the number of reported white-tailed deer carcasses (MDT) and the number of reported accidents with wild animals (MHP). A possible explanation is the increase in traffic volume combined with the relatively low search and reporting effort by MDT for white-tailed deer carcasses between April and October, and the possibility that deer carcasses may be obscured by high vegetation in summer. Another possible explanation is that tourists, who mostly visit the region during the summer months, are more likely to report accidents to law enforcement agencies than individuals who live in the region. Furthermore, individuals with local knowledge and experience (e.g. Bruce Friede, MDT, Appendix A: Contact Details of Interviewed Individuals) have stated that most of the collisions take place during the winter months. However, we can only hypothesize which of the two datasets reflects a potential seasonal fluctuation in wildlife-vehicle collisions more accurately.

Far more female white-tailed deer carcasses were reported than male. This seems to be related to an uneven sex ratio. It is not uncommon for deer populations to have uneven sex ratios with far more females than males (Mackie *et al.*, 1998), including in the Seeley-Swan area (Mundinger, 1979). Collisions with wild animals are reported on all days of the week with no consistent differences between weekdays and weekend days. Most of the reported accidents occurred in the late afternoon, evening and early morning, which coincides with increased white-tailed deer activity around sunset and sunrise (Mackie *et al.*, 1998). Human injuries and human fatalities seemed to occur in a diffuse pattern along the transportation corridor; they did not appear to be concentrated in certain areas, and there was only partial overlap with the zones that have the highest collision frequency.

The MDT and MHP data sets showed that white-tailed deer or deer carcasses and collisions with wild animals occur along most of MT 83. However, there are certain road sections that have a higher frequency than others. We identified 27 road sections based on the MDT data set, and 17 of these had least partial overlap with the road sections identified based on the MHP data set.

5. ROAD, TRAFFIC AND LANDSCAPE CHARACTERISTICS ASSOCIATED WITH WHITE-TAILED DEER COLLISION ZONES

5.1. Introduction

Almost 95% of all reported animal-vehicle collisions along MT 83 relate to white-tailed deer (*Odocoileus virginianus*) (see chapter 4). In this chapter we investigate whether white-tailed deer collision zones are associated with selected road-, traffic- and landscape variables. The results may provide insight in what changes to the road and surrounding landscape may help reduce the number of collisions with white-tailed deer (cf. Puglisi *et al.*, 1974; Finder *et al.*, 1999; Huijser *et al.*, 2000; Nielsen *et al.*, 2003; Rogers, 2004; Malo *et al.*, 2004; Seiler, 2005). In addition, the findings may provide an understanding of what characteristics of the road and surrounding landscape influence deer movements, as well as to identify and prioritize locations for potential mitigation measures aimed at reducing white-tailed deer-vehicle collisions. Finally, the results may show the benefit of an integrated approach that not only considers measures on the road and right-of-way itself, but that also considers habitat and land use in the surrounding landscape.

5.2. Methods and Materials

5.2.1. Low and High Frequency White-Tailed Deer Collision Zones

Researchers used the MDT data sets for the southern and northern section of MT 83 (RP 0.0-47.8 and 80.0-91.1, collected between 1998-2003, see chapter 4) to identify relatively low and high frequency white-tailed deer collision zones. These two data sets had a spatial resolution of 0.1 mi (160.9 m) (see chapter 4). The team did not use the MDT data set for the central section (RP 47.8-80.0) because of the limited spatial resolution (1.0 mi instead of 0.1 mi) and because the data set did not distinguish between white-tailed and mule deer (see chapter 4). The MHP data set was not used, because it did not contain information about the animal species concerned (see chapter 4).

High frequency collision zones varied in length and included all 0.1 mile long road sections in the southern and northern section that had a “very high deer value” and all adjacent 0.1 mile long road sections that had a “high deer value” (see chapter 4 and Appendix C) (Table 5-1 and Table 5-2). Similarly, low frequency collision zones varied in length and included all 0.1 mile long road sections that had an “absent deer value” and all adjacent 0.1 mile long road sections with a “very low deer value” (see chapter 4, Appendix C) (Table 5-1 and Table 5-2). The remaining 0.1 mile road sections with "high" or "very low" deer values were not adjacent to 0.1 mi road sections with a "very high" or "absent" deer value and were not included in the low and high frequency collision zones. The low and high frequency collision zones are mapped in Figure 5-1 and Figure 5-2. The low and high frequency collision zones had an average of 0.6 and 16.7 reported white tailed deer carcasses per mile (1,609 m) respectively between 1998 and 2003.

Table 5-1: Low and high frequency white-tailed deer collision zones in the southern and northern sections of MT 83. RP = Reference Post.

Low frequency zones (RP)	Length (mi)		High frequency zones (RP)	Length (mi)
0.0-1.8	1.9		2.8-3.2	0.5
2.2-2.3	0.2		3.4-5.6	2.3
6.2-6.3	0.2		5.9-6.1	0.3
14.0-15.1	1.2		6.5-8.6	2.2
15.5-15.7	0.3		8.9-13.3	4.5
16.2-17.6	1.5		15.9-16.1	0.3
20.6-21.8	1.3		17.7-18.2	0.6
22.7-22.8	0.2		18.9-20.1	1.3
23.7-23.8	0.2		34.9-35.2	0.4
24.5-26.0	1.6		35.8-36.3	0.6
26.2-26.8	0.7		36.9-37.1	0.3
28.1-28.9	0.9		37.9-38.1	0.3
29.3	0.1		39.8-40.4	0.7
30.2-30.8	0.7		41.4-41.7	0.4
31.2-32.8	1.7		41.9-42.1	0.3
33.2-33.8	0.7		42.3-43.1	0.9
34.2-34.8	0.7		43.8-44.1	0.4
38.7-38.8	0.2		45.9-46.1	0.3
39.4-39.7	0.4		82.9	0.1
40.6-41.3	0.8		83.2-83.6	0.5
44.2-44.3	0.2		84.3-84.5	0.3
44.7-44.8	0.2		85.5-85.7	0.3
46.6-46.8	0.3		85.9	0.1
47.2-47.8	0.7		86.2-86.4	0.3
80.0-82.8	2.9		87.1	0.1
83.8-84.0	0.3		88.5-88.6	0.2
86.5-86.9	0.5			
87.3-88.3	1.1			
88.8	0.1			
89.2-90.3	1.2			

Table 5-2: Summary statistics for low and high frequency white-tailed deer collision zones in the southern and northern sections of MT 83.

Collision zone type	Cluster s (n)	Mean length (mi)	SD	Median length (mi)	Range length (min.-max.) (mi)	Total length zones (mi)
Low	30	0.767	0.663	0.700	0.1-2.9	23.0
High	26	0.712	0.955	0.350	0.1-4.5	18.5

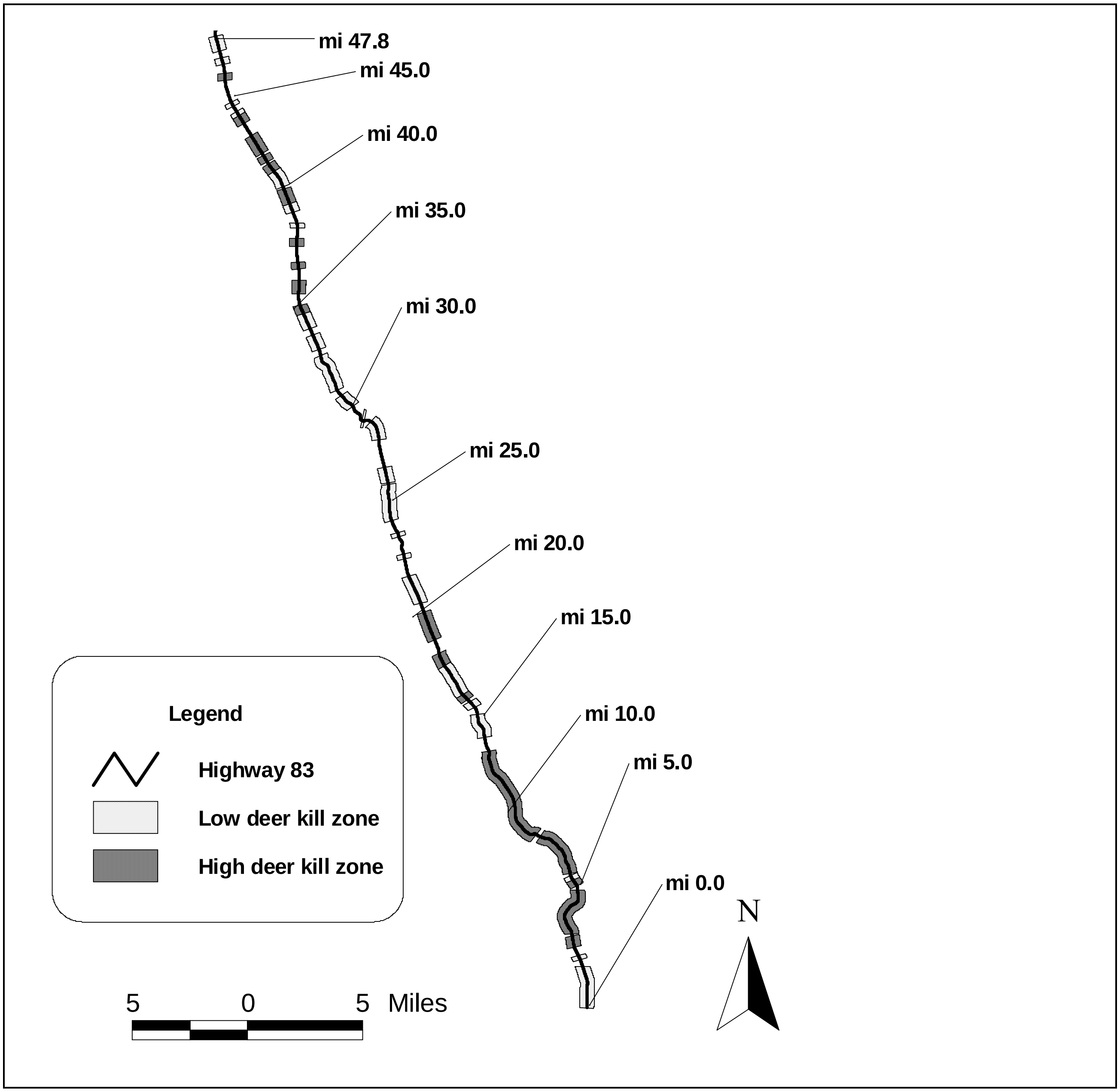


Figure 5-1: Low and high frequency white-tailed deer collision zones for the southern section of MT 83.

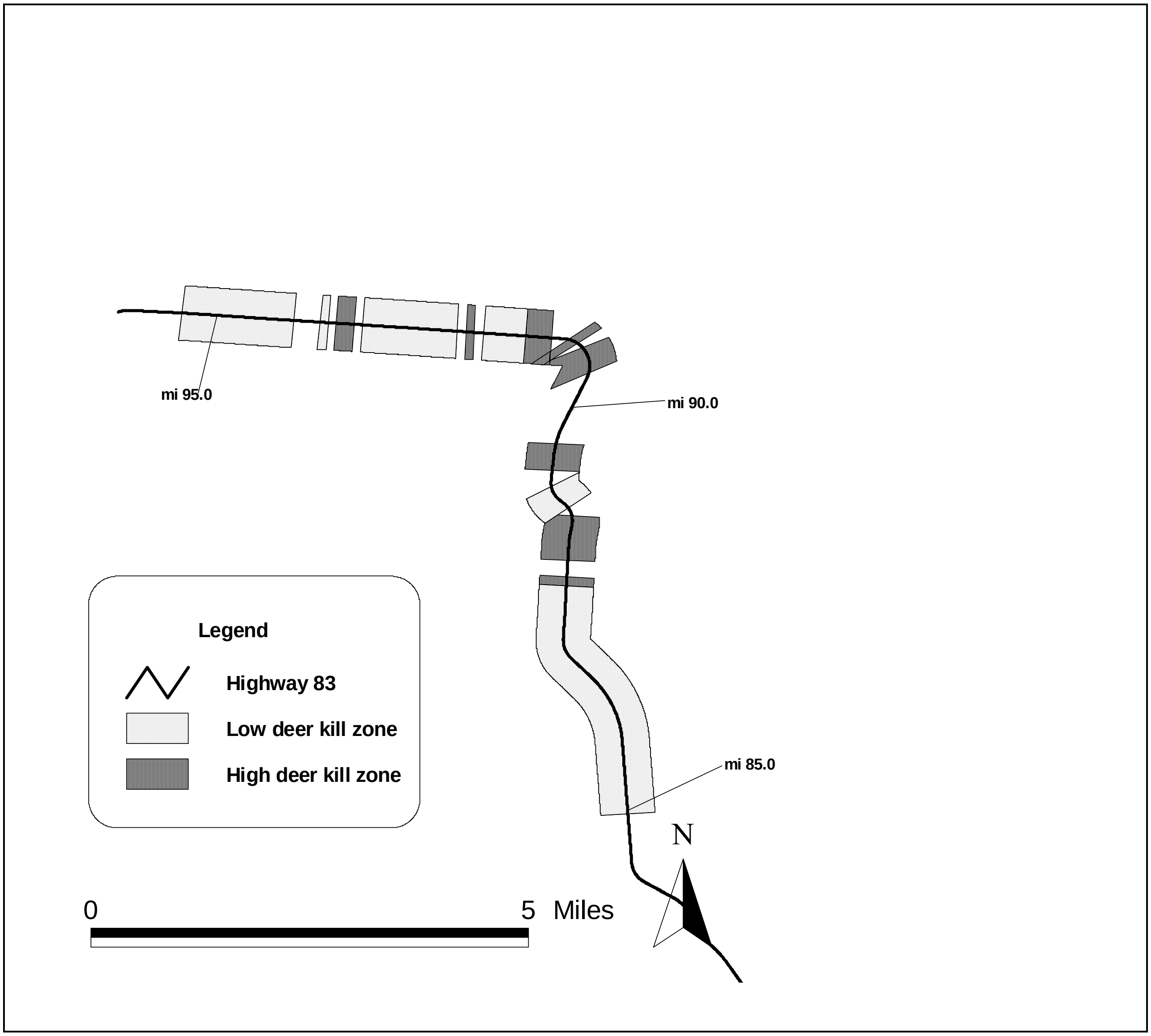


Figure 5-2: Low and high frequency white-tailed deer collision zones for the northern section of MT 83.

5.2.2. Spatial Scales

The research team measured selected road-, traffic-, and landscape variables in the low and high frequency collision zones at different spatial scales through Geographical Information System (GIS) analyses and direct field observations. For the GIS analyses a zone started 0.05 mi before the first and ended 0.05 mi after that last 0.1 RP in a low or high frequency collision zone. For example, the high frequency collision zone between RP 15.9-16.1 started at RP 15.85 and ended at RP 16.15. The team plotted these low and high frequency collision zones in a GIS (ArcView 3.3) (ESRI, 1999) (Coordinates: NAD 1983 State Plane Montana FIPS 2500). Researchers defined GIS variables based on data layers from different sources (see section 5.2.3) and conducted the GIS analyses at three different spatial scales. The GIS variables were measured in a buffer zone adjacent to the road that was 1000 m, 500 m or 100 m wide (measured from the center of the road) for each side of the road (Figure 5-3). Thus the total width of the zones for the three different spatial scales was 2000 m, 1000 m and 200 m. The length of a zone corresponded with the length of the low or high frequency collision zone.

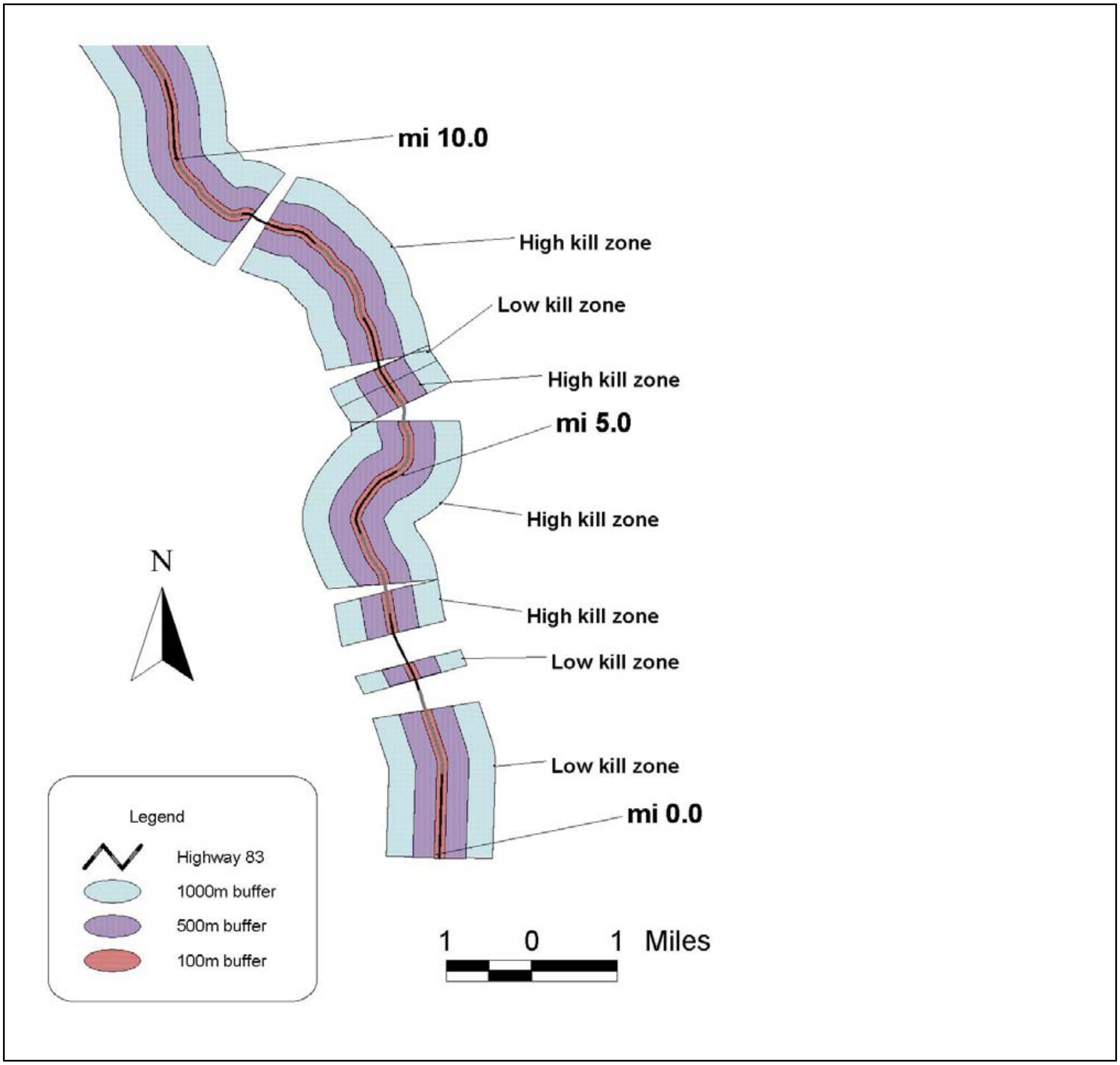


Figure 5-3: An example of the 100 m, 500 m and 1000 m buffer zones for the low and high frequency collision zones at the southern end of MT 83.

In addition to the GIS analyses, the team also measured road- and landscape variables in the low and high frequency collision zones through direct field observations. In July and August 2004 researchers visited all 0.1 mile long road length units (N=415) within each low and high frequency collision zone to record road-, traffic- and landscape characteristics. A road length unit started and ended halfway between 0.1 mile stations. For example, for RP 12.7 a road length unit started at 12.65 and ended at 12.75 (Figure 5-4). Landscape characteristics were recorded in a zone that extended up to 100 m from the edge of the pavement on both sides of the road. Thus a zone measured 0.1 mile (160.9 m) by 200 m plus the road width (Figure 5-4). When road- or landscape features were not present within the road length unit concerned, the team also examined the two adjacent road length units within a 100 m radius (measured from the edge of the pavement at the beginning or end of a road length unit) as a maximum (see section 5.2.4). Thus the variables obtained through direct field observation were taken at each 0.1 RP and related to an oval shaped area (Figure 5-4).

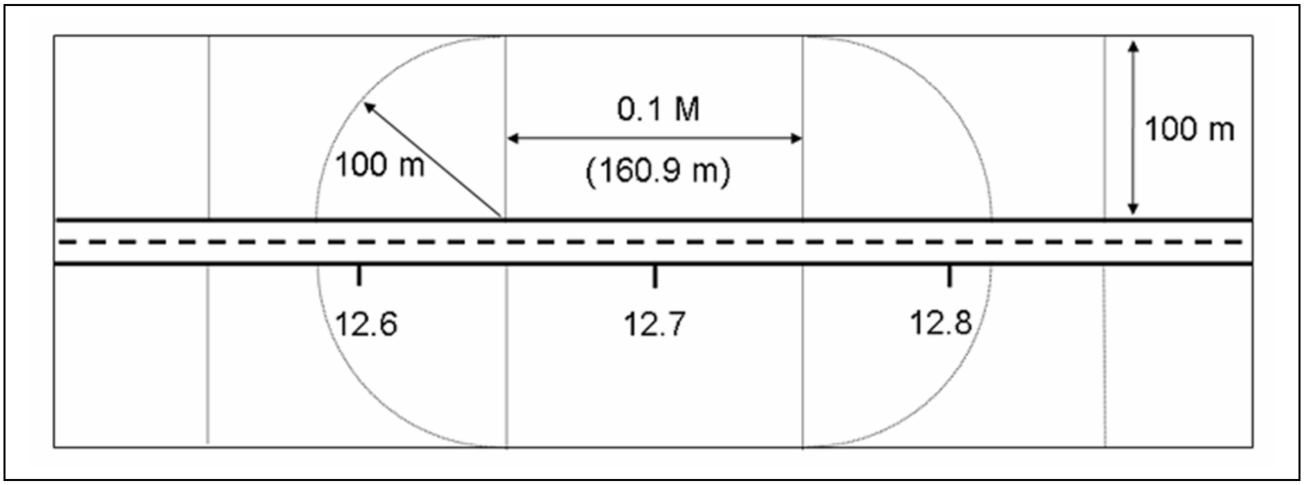


Figure 5-4: Hypothetical example of a road section with 0.1 mi stations, the 0.1 mi road length units and a 100 m wide zone with a 100 m radius on either side of the road.

5.2.3. Landscape Variables through GIS

Researchers used four different sources of spatial information for the GIS analyses:

- R1-Vegetation Mapping Project dataset (VMP) (Brewer *et al.*, 2003; 2004). The R1-VMP dataset is based on Landsat ETM+ satellite imagery with 30x30 m pixels from July and August 2002.
- Topographical maps. The topographic maps are digital raster graphics generated between 1965 and 1994 (for different parts of the study area) with a 1:24,000 scale (U.S. Geological Survey, 1994).
- U.S. Geological Survey (USGS) aerial photographs. Aerial photographs were black and white Digital Orthophoto Quarter-Quadrangles (DOQQs) at 1 m resolution 1990-2003 (southern section, RP 0.0-20.0, 1995; southern section RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991) (U.S. Department of the Interior, 1992).
- Low volume roads layer GIS shape file. This file contained roads other than MT 83 and was obtained from a shapefile generated by the MDT (Montana Department of Transportation, 2005).

All data was available in NAD 1983 State Plane Montana FIPS 2500 coordinates and projected in Lambert Conformal Conic. The R1-VMP dataset was used to define and measure areas of forest, shrubland, grassland, sparsely vegetated areas, and waters. The aerial photos were used as a background layer to produce digitized layers for open forest, cleared areas, arable land, and built-up areas (Table 5-3) as these variables were not or not satisfactory defined within the R1-VMP dataset, but were easily identified in the aerial photographs. The cleared area layer (aerial photos) was combined with the grassland variable (R1-VMP dataset) and the built-up area (aerial photos) was combined with the sparsely vegetated variable (R1-VMP dataset) based on their similar vegetative and land use characteristics. All grid layers were then merged to provide a land use layer for analysis.

Table 5-3 describes the GIS landscape variables generated for the low and high collision zones in the southern and northern section.

In addition, an open water and wetlands layer and a river layer were digitized from the topographical and aerial photos (Table 5-3). The open water and wetlands layer consisted of "marshes and swamps" as marked on the topographical maps as well as open bodies of water identified from the aerial images. The low volume roads layer obtained from MDT (roads other than MT 83) was supplemented with other low volume roads identified from aerial photos. However, logging roads through forest with thick cover were not included as they could not be reliably identified. The area of open water and wetlands and the lengths of rivers and roads within each collision zone were calculated for each buffer zone using Xtools (Oregon Dept. of Forestry, 2003).

In addition, two other variables were calculated. Heterogeneity was measured as the length (m) of contact lines between polygons within each collision zone. Finally, the Shannon diversity index was calculated for each collision zone (Table 5-3) (Begon *et al.*, 1996).

Before starting the data collection researchers determined whether they expected an increase or decrease in the values for the variables to result in an increase or decrease in the number of road-killed white-tailed deer. This allowed the team to conduct one-sided tests rather than two-sided tests, making it more likely to identify effects of those landscape variables studied.

Table 5-3: The GIS variables generated for the low and high collision zones in the southern and northern sections.

Variable	Definition	Source
FOREST_GIS (ha)[?]	Greater than 10% tree cover.	Northern Region Vegetation Mapping Project (R1-VMP), tree dominated variable.
OPEN_FOREST_GIS (ha)[?]	Scattered trees, not dense, i.e. forest floor seen through gaps in canopy.	Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991).
SHRUBLAND_GIS (ha) [?]	Greater than 10% shrub cover and less than 10% tree cover.	Northern Region Vegetation Mapping Project (R1-VMP), shrubland variable.
CLEARED_GRASS_GIS (ha)[?]	A combination of : 1) Cleared areas i.e. no vegetation seen, within forested areas. 2) Grassland areas, i.e. less than 10% shrub and/or tree cover.	1) Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991). 2) Northern Region Vegetation Mapping Project (R1-VMP), grassland variable.
ARABLE_LAND_GIS (ha)[?]	Crops or plowed parcels with bare soil.	Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991).
BUILT-UP_GIS (ha)[?]	A combination of : 1) Intensively developed area, i.e. residential or industrial buildings and premises, including residential and other buildings scattered in forested areas. 2) Sparsely vegetated area, i.e. less than 10% vegetated cover of any type (e.g. gravel or pavement)	1) Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991). 2) Northern Region Vegetation Mapping Project (R1-VMP), sparsely vegetated variable.
WATER_GIS (ha)[?]	Large bodies of water, i.e. lakes.	Northern Region Vegetation Mapping Project (R1-VMP), water variable.
WATER_WETLAND_GIS (ha)[?]	Open water basin, lakes, and “marsh or swamp”.	1) USGS topographic maps (1965-1995) 1:24,000 scale.

Variable	Definition	Source
WATER_WETLAND_GIS (ha)[?]	Open water basin, lakes, and "marsh or swamp".	2) Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991).
ROADS_GIS (m)[?]	Length of low volume paved or unpaved roads (other than MT 83), does not include logging roads in dense cover.	1) Montana Department of Transportation (2005). 2) Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991).
RIVERS_GIS (m)[+]	Length of rivers and major tributaries or streams as identified on aerial and topographic maps.	1) USGS topographic maps (1965-1995) 1:24,000 scale. 2) Aerial photography (southern section, RP 0.0-20.0, 1995 and RP 20.0-47.8, 2003; northern section, RP 80.0-91.1, 1990-1991).
FOREST_EDGE_GIS (m)[+]	Length of transition from cover (forest or open forest) to open areas (shrubland, cleared area or grasslands, or arable land, but not to open water).	Generated from the land use data layer.
HETEROGENITY_GIS[+]	Sum of the perimeters of each landscape variable polygon within each collision and buffer zone minus the buffer zone perimeter.	Generated from the land use data layer.
DIVERSITY_GIS[+]	$H = -\sum_{i=1}^{s} p_i \ln p_i$ Shannon Diversity Index. The proportion of landscape variable *i* (area variable) relative to the total number of landscape variables (p_i) (all area variables) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln(p_i)$). The resulting product is summed for all landscape variables, and multiplied by –1.	Generated from the land use data layer.

[?] = Direction of possible effect is unknown; [+] = Increase in white-tailed deer-vehicle collisions expected if feature is present or increases.

The research team expected the area of forest, open forest, shrubland, cleared area or grassland, arable land, built-up areas, water, and water and wetlands (FOREST_GIS THROUGH WATER_AND_WETLANDS_GIS;Table 5-3) to have an influence on white-tailed deer population density and white-tailed deer-vehicle collisions, but they were uncertain of the direction of their possible effect. Forests and agricultural lands can be important to white-tailed deer, but their population density is reduced if these habitat types are large scale and homogenous. If there is a mix of habitats that provide both cover and food and if there is an abundance of transition zones, white-tailed deer usually have relatively high population density (Puglisi et al., 1974; Mundinger, 1979; Leach, 1982; Peek, 1984; Arno *et al.*, 1987; Finder et al., 1999; Nielsen *et al.*, 2003).

Researchers were also uncertain of the effects of low volume roads and rivers on deer vehicle collisions. Low volume roads (ROADS_GIS;Table 5-3) may be associated with human disturbance, which could either discourage deer or provide "shelter" from predators. Low volume roads may also be associated with open or cleared areas with shrubs, grasses and herbs, edge habitat, buildings, and gardens, which provide food or feeding opportunities. Finally low volume roads may provide easy travel corridors for animals. Therefore the team was uncertain of the direction of the possible effect of low volume roads. Rivers (RIVERS_GIS;Table 5-3) may form a barrier to deer which could lead to fewer collisions. However, rivers may also cause animals to travel parallel to the river, and the riparian habitat alongside rivers may be an attractant to the deer, potentially resulting in more white-tailed deer road kills where the road is near river and riparian habitat (Leach, 1982; Leach & Edge, 1994; Rogers, 2004). Finally researchers expected edge habitat (FOREST_EDGE_GIS), habitat heterogeneity (HETEROGENITY_GIS), and habitat diversity (DIVERSITY_GIS) to be positively associated with high frequency collision zones (Mundinger, 1979; Finder *et al.*, 1999; Nielsen *et al.*, 2003; Rogers, 2004).

5.2.4. Road, Traffic, and Landscape Variables through Field Observations

The research team selected road-, traffic-, and landscape variables (Table 5-4) that were expected to influence white-tailed deer movements towards and across the road, or otherwise affect the number of road-killed white-tailed deer. Habitat types and linear habitat features related to cover and food were especially well represented among the explanatory variables since they were expected to have a strong influence on the presence of white-tailed deer and how deer move through the landscape (cf. Finder *et al.*, 1999; Nielsen *et al.*, 2003). Before conducting the study the direction of the possible effect of some of the variables was hypothesized. Researchers predicted whether a particular variable might increase or decrease deer-vehicle collisions or whether the direction of a possible effect was unknown or unpredictable. The predictions were based on the results of previous studies (Bellis & Graves, 1971; Puglisi *et al.*, 1974; Mundinger, 1979, Leach, 1982; Leach & Edge, 1994; Peek, 1984; Arno *et al.*, 1987; Gunther *et al.*, 1998; Clevenger *et al.*, 2002; Seiler, 2003; Rogers, 2004; Seiler, 2005) (Table 5-4). The predictions facilitated the use of one-sided tests rather than two-sided tests, making it more likely to identify possible effects of the road-, traffic and landscape variables studied.

The team calculated the Annual Average Daily Traffic volume (AADT) (VEHICLES), based on data provided by MDT, for different sections of MT 83, with 0.1 mile increments (Table 5-5). The average AADT for 1998-2002 was selected to match the MDT white-tailed deer carcass data set (1998-2003) as close as possible (AADT data from 2003 were not available at the time). This value was applied to relatively homogenous road sections with regard to the presence of building or villages (Table 5-5). The average length of the road sections with the same traffic volume was 9.8 mi (15.8 km).

The road width (ROAD_WIDTH, W-variable, see section 5.2.4) of the road was measured from the edge of the pavement on one side of the road to the edge of the pavement on the other side of the road. Along with the width of the road, researchers expected traffic volume (VEHICLES) and the maximum speed limit (SPEED) to have an influence on the number of road-killed white-tailed deer, but were uncertain of the direction of the possible effect. Wide and busy road sections are more risky to crossing white-tailed deer (more road-killed individuals), but the high traffic volumes and the width of the road may also keep the animals from approaching the road or attempting to cross the road, potentially resulting in fewer road-killed individuals (cf. Seiler, 2003; Seiler, 2005). Higher vehicle speeds are usually associated with an increase in road-kill (Gunther *et al.*, 1998; Seiler, 2005), but this relationship is often confounded because roads with relatively high speed limits are usually wider and have higher traffic volume which could discourage animals from trying to cross the road. Furthermore, white-tailed deer are known to use several types of under- and overpasses (e.g. Clevenger *et al.*, 2002), and the presence of such structures may lead to fewer road-killed white-tailed deer. The team recorded the presence of all possible passages for deer (PASSAGE, minimum 4 ft (1.2 m) high, not-inundated, P-variable, see later), and not just those that may have been specifically designed for wildlife or white-tailed deer.

Table 5-4: Road, traffic, and landscape variables obtained through direct field observations for each 0.1 mi station.

Variable	Description and expected direction of effect	P	D	Q	O	W	G	S
VEHICLES	Average Daily Traffic volume ($N^?$)							
WIDTH	Width of road ($m^?$)					$W^?$		
SPEED	Legal speed limit ($mi/hr^?$)							
PASSAGE	Presence of over- or underpass ($0^+/1^-$)	P^-						
MOWN_ROW	Width of mown part of right-of-way (m^-)					W^-		
ROAD_SIGHT	Sight distance on road (m^-)		D^-					
SIDE_SIGHT	Sight distance to the side of the road (m^-)		D^-					
LANDSCAPE	Forest$^?$, agricultural$^?$, residential$^?$, prairie$^-$ (natural dry grassland), wetland$^+$ (inundated vegetation).							
FOREST	Forest, woodland (W>20 m or L:W <10:1)	$P^?$	$D^?$	$Q^?$			G^+	S^+
FOREST_TYPE	Deciduous ($1^?$); Coniferous ($2^?$); Mixed ($3^?$)							
FOREST_BURN	Burned ($0^?$=not visible, $1^?$= visible, but new growth, $2^?$= visible, no new growth)							
FOREST_CUT	Cut ($0^?$=not visible, $1^?$= visible, but new growth, $2^?$ =visible, no new growth)							
BARRIER	Concrete (“Jersey”) barrier or “Texas rail”	$P^?$	$D^?$	$Q^?$	O^+			
GUARD_RAIL	Guard rail	$P^?$	$D^?$	$Q^?$	O^+			
FENCE	Impermeable fence, ≥6 ft	$P^?$	$D^?$	$Q^?$	O^+			
ROAD	Other road (paved, gravel, driveway)	$P^?$	$D^?$	$Q^?$	O^+			
LIGHTS	Street lights or lamp posts	P^-	D^+	Q^-				
GRASSLAND	Natural grassland, meadow or pasture	$P^?$	$D^?$	$Q^?$				
GRASS_ROW	Width grass in right-of-way (sum 2 sides)	$P^?$	$D^?$	$Q^?$	$O^?$	$W^?$		
ARABLE	Agricultural crops, ploughed fields	$P^?$	$D^?$	$Q^?$				
BUILDINGS	Houses, barns, non-vegetated premises	$P^?$	$D^?$	$Q^?$				
GREEN	Urban green, garden or vegetated premises	P^+	D^-	Q^+				

Variable	Description and expected direction of effect	P	D	Q	O	W	G	S
EDGE_HABITAT	Transition cover-open habitat	P^+	D^-	Q^+	O^+			
TREE_LINE	Line of trees (no cover < 2 m)	P^+	D^-	Q^+	O^+			
HEDGEROW	Hedgerow (cover <2 m, W ≤20 m and L:W ≥10:1)	P^+	D^-	Q^+	O^+	W^+		S^+
RIPARIAN	Riparian habitat	P^+	D^-	Q^+	O^+			
SLOPE	Slope (>45 degrees, ≥5 m)	$P^?$	$D^?$	$Q^?$	O^+			
GULLY	Linear depression (≥2m deep, no riparian/water)	P^+	D^-	Q^+	O^+			
RIDGE	Linear upheaval (≥ 2 m high)	P^+	D^-	Q^+	O^+			
OPEN WATER	Open water (> 10 m wide and > 1 m deep)	$P^?$	$D^?$	$Q^?$	O^+			
WATER	Permanent or seasonable water source	P^+	D^-	Q^+				

P = Presence of a landscape element (0/1); D = Distance to road (m); Q= Quantity (% for both sides combined along a 0.1 mi long road length unit); O= Perpendicular orientation (0/1) (0= parallel, 0-45 degrees, 1= perpendicular, 46-90 degrees; W= Width (m); G= Presence of grass and/or herbs (0/1); S= Presence of shrub layer (deciduous, branches and leaves less than 2 m from ground) (0/1); L= Length (see text and Figure 5-4 fur further explanation). $^?$ = Direction of possible effect is unknown; $^+$ = Increase in white-tailed deer-vehicle collisions expected if feature is present or increases; $^-$ = Decrease in white-tailed deer-vehicle collisions expected if feature is present or increases.

Table 5-5: Annual Average Daily Traffic volume (AADT; 1998-2002) for the different road segments in the southern and northern section based on data provided by MDT.

Station ID	Station location	Road section		AADT
		RP Low	RP High	
00050432	RP 1, 1 mi N of MT 200 (A-66)	0.0	6.9	2054
00060432	RP 10.5, 4 mi SE of Seeley Lake	7.0	15.2	2318
00010232	RP 19, 4.5 mi NW of Seeley Lake	15.3	25.4	1304
00020232	RP 32.5, at Pierce Lake	25.5	36.0	984
00030232	RP 44.5, I mi SE of Condon	36.1	47.8	1144
00130224	RP 80, 2.5 mi SE of FAS 209	80.0	91.1	1672

RP = Reference Post

For each 0.1 mile station, the team recorded the shortest sight distance on the road (ROAD_SIGHT), estimating the distance until the yellow center line disappeared from sight (D-variable, see later in this section). If the yellow line only disappeared marginally and if at least one of the white lines on the side of the road was still visible, then that location was ignored; a deer would still have been clearly visible to the driver. Of the two sight distances measured for the two opposite directions for a given station, the shorter of the two distances was used. In addition, researchers recorded the shortest sight distance perpendicular to the road (SIDE_SIGHT) within each road length unit (0.1 mi long). This variable was measured from the edge of the pavement to the edge of the visual barrier (e.g. thick cover, building) (D-variable, see later in this section). Tall grass-herb vegetation in the right-of-way can also reduce sight distance for drivers. Therefore we also measured the width of the mown zone, cumulative for both sides of the road (MOWN_ROW). The sight distance (ROAD_SIGHT, SIDE_SIGHT and MOWN_ROW) was expected to be negatively associated with white-tailed deer collision zones. With limited sight distance drivers may not see the animals until they are relatively close, leaving them no or little time to react.

The research team investigated the effect of landscape characteristics at two levels: 1) through a classification of major landscape types (LANDSCAPE), and 2) through a range of landscape features present (FOREST through WATER) (Table 5-4). The team distinguished five major landscape types (LANDSCAPE): forest, prairie (dominated by dry natural grasslands), wetlands (dominated by inundated vegetation, but not by open water), agricultural (dominated by grasslands and arable lands), and residential (dominated by buildings, premises, urban green, roads and non-vegetated gravel or paved areas). In order for a 0.1 mile long road length unit to be classified as a forest landscape (LANDSCAPE) for example, the trees and shrubs had to cover at least half of a 0.1 mile long road length unit (i.e. at least 0.1 mile long, cumulative for the two sides of the road, Q-variable, see later in this section) and at least one of the two adjacent 0.1 mile road length units had to qualify as that landscape type as well. Large scale and homogeneous forests and agricultural lands, especially arable land (Finder *et al.*, 1999), support relatively few deer. However, thick forest cover is important winter habitat as these areas provide thermal cover and minimize snow accumulation on the ground. This reduces the energetic demands that low temperatures and high snow accumulation impose on deer movements and feeding in the winter (Peek, 1984). A mixture of the forests, grasslands and other landscape elements with an abundance of transition zones between cover and open areas is generally associated with high deer numbers and deer-vehicle collisions (Puglisi *et al.*, 1974; Peek, 1984; Finder et *al.*, 1999; Nielsen *et al.*, 2003).

With these confounding observations, the effects of forest and agricultural landscape types on the number of road-killed with-tailed deer could not be predicted. The same is true for residential areas. Fertilized lawns and people may provide food and shelter from predators (Nielsen *et al.*, 2003; Finder et *al.*, 1999), but high density residential areas probably have too few green areas, too many barriers, and too much human-associated disturbance for deer. The landscape type prairie however, can be expected to be associated with relatively few deer-vehicle collisions as these are large scale open areas with no or little cover. Wetlands on the other hand are important to white-tailed deer and they seem to be positively associated with deer-vehicle collisions (Mundinger, 1979; Leach, 1982; Leach & Edge, 1994; Peek, 1984; Arno *et al.*, 1987; Finder *et al.*, 1999; Rogers, 2004).

Forests can support high numbers of white-tailed deer; especially when forests are mixed with grasslands and/or arable lands, and if there is a large number of transition zones between cover and open areas (Puglisi *et al.*, 1974; Peek, 1984; Finder *et al.*, 1999; Nielsen *et al.*, 2003). The presence of forest (FOREST) (P-variable, see later in this section) is not restricted to within the major landscape type "forest" (a category of LANDSCAPE). In this study a forest (FOREST) could also be a forest fragment in an agricultural or prairie landscape (LANDSCAPE), for example. Whenever FOREST was present researchers also recorded whether it was pine, deciduous, or mixed (FOREST_TYPE) and whether there were signs of recent burning (FOREST_BURN) or cutting (FOREST_CUT). Deciduous forests, especially in riparian areas, can provide good year-round habitat for white-tailed deer (Peek, 1984). However, deciduous forest may not always be associated with true riparian habitat and the effect of deciduous forest on the number of deer-vehicle collisions could not be predicted. Logging and forest fires can result in habitat that is (temporarily) unattractive to deer because of the lack of food or the accumulation of snow in winter (difficult feeding and travel), but it can also benefit white-tailed deer through the temporary availability of e.g. lichens from fallen trees, the increase of grasses and herbs as a result of increased light availability, and the growth or re-growth of trees and shrubs that are within reach for a deer (Mundinger, 1979; Arno *et al.*, 1987). However, when logging and forest fires are relatively intense and large scale, there may not be sufficient cover available nearby, and deer may avoid these areas or reduce their use of these areas (Peek, 1984).

Researchers expected concrete barriers (BARRIER), guard rails (GUARD_RAIL), high fences (FENCE), and other roads (ROADS) parallel to MT 83 to hinder the movement of white-tailed deer and to discourage them from crossing the road (e.g. Carbaugh *et al.*, 1975). However, they also expected white-tailed deer to cross the road more frequently at the end of a concrete barrier, guard rail, fence or where MT 83 intersects with another road. Therefore it was difficult to predict the direction of the possible effect of these variables on the number of white-tailed deer–vehicle collisions. However, a perpendicular orientation of these variables could be expected to lead to more white-tailed deer-vehicle collisions as a perpendicular orientation may guide the animals towards the road. Street lights or lamp posts (LIGHTS) increase visibility for drivers at night and white-tailed deer may avoid such light sources. Thus lights may be associated with fewer white-tailed deer-vehicle collisions. Note: along MT 83 concrete barriers are used on the side of the road to protect the road surface and vehicles from falling rocks.

Grasslands (GRASSLAND), grass-herb vegetation in the right-of-way (GRASS_ROW) and agricultural crops (ARABLE) can be attractive food sources for white-tailed deer. However, if these variables are not mixed with habitat that provides cover, they may not be associated with high white-tailed deer-vehicle collision numbers. Note: GRASSLAND related to natural grassland, meadows or pastures, but it did not include the grass-herb vegetation in the right-of-way.

Houses, barns, and gravel or non-vegetated premises (BUILDINGS) have little to offer to white-tailed deer, and if there are no other habitat types that provide cover and food, it is likely that relatively few white-tailed deer collisions will occur in such areas. However, people who live in these buildings may provide deer with food, either directly (purposefully feeding deer) or indirectly (e.g. deer feed on hay or other food intended for livestock). Therefore the direction of the potential effect of this variable was unknown. Urban green, garden or vegetated premises (GREEN) are often associated with buildings. Urban green may be an attractant to deer, especially in semi-arid areas.

Edge habitat (EDGE_HABITAT, TREE_LINE, HEDGEROW) and riparian areas (RIPARIAN) are considered an attractant to white-tailed deer (Puglisi *et al.*, 1974; Mundinger, 1979; Leach, 1982; Arno *et al.*, 1987; Leach & Edge, 1994; Finder *et al.*, 1999; Rogers, 2004). These variables are likely to be associated with high frequency collision zones. Note: EDGE_HABITAT related to the transition from cover (e.g. forest, woodland or hedgerow) to open areas, but it did not include transitions from cover to the grass-herb vegetation in the right-of-way.

Steep slopes along the roadside (SLOPE) may discourage animals from approaching the road (fewer collisions). However, animal movements may also be funneled to the end or beginning of a slope along the road (more collisions). Therefore the direction of the potential effect of steep slopes was unknown. White-tailed deer may follow gullies (GULLY) and ridges (RIDGE) when they move through the landscape (Finder *et al.*, 1999). Therefore these two variables could be associated with high frequency deer kill zones.

Open water (OPEN_WATER) is “unsuitable” habitat and can form a barrier to white-tailed deer movements, but the banks of a lake or river may also funnel white-tailed deer movements, and the water itself may be an attractant too. Potential water sources for drinking (WATER) included smaller streams and wetlands and could be an attractant to white-tailed deer (Finder *et al.*, 1999).

The research team also distinguished additional habitat categories for orchards and railroads, but neither of these were observed in the low and high collision zones. In addition, MT 83 did not have a median.

Researchers measured several aspects of the same landscape features. These aspects translated into P-, D-, Q-, O-, W-, G-, and S-variables (Table 5-4). The presence of a landscape feature (a P-variable) corresponded to its presence in the oval shape around each 0.1 mile station (Figure 5-4). The distance (a D-variable) was measured with an optical range finder (Ranging, Bushnell TLR 75, Overland Park, KS, USA) and related to the minimum distance from the landscape feature to the edge of the road surface. If the landscape feature was only present in one of the adjacent 0.1 mi road length units, the minimum distance was measured from the edge of the road surface of the original section, with the 100 m radius as a maximum. If the landscape element was not present there either, the distance was set at 101 m. Quantity (a Q-variable) was defined as the percentage of a 0.1 mile long road length unit that a landscape feature was present on along either side of the road. The maximum value for a Q –variable was 100% (50% cover on each side of the road). The Q-variables only applied to the road length units concerned; not to the adjacent units. A perpendicular orientation (an O-variable) of a linear landscape feature corresponded to it lying at a 45-90˚ angle from the road. The landscape feature had to be present in the oval shown in Figure 5-4. The W-variables related to the width of the landscape feature concerned. The width of the grass-herb vegetation and the mown zone in the right-of-way (GRASS_ROW, MOWN_ROW) related to the width for both sides of the road combined. The G- and S-variables related to the presence of a grass-herb or a shrub layer in the landscape feature concerned. Finally it is important to note that the values of the P-, D-, O-, W-, G-, and S-variables were not only influenced by the situation in the road length unit concerned, but also by the situation in the adjacent units, as long as they were within a 100 m radius from the edge of the original unit. The same applied to the PASSAGE, LANDSCAPE, FOREST, FOREST _TYPE, FOREST_BURN, and FOREST_CUT variables.

5.2.5. Analyses for GIS Data

The research team compared the landscape variables obtained through GIS (Table 5-3) between low and high frequency collision zones to identify parameters that may be positively or negatively associated with white-tailed deer-vehicle collisions.

The variables with surface area units (ha) (FOREST_GIS through WATER_WETLAND_GIS) were standardized to percentages of the area covered by the buffer zone. Variables relating to the length of a landscape feature (ROADS_GIS through FOREST_EDGE_GIS) were standardized to m/ha (based on the area covered by the buffer zone). The remaining variables (HETEROGENITY_GIS and DIVERSITY_GIS) did not require standardization.

Researchers calculated the mean of all variables (FOREST_GIS through DIVERSITY_GIS) for low and high frequency collision zones. They used a t-test to test for possible differences ($P<0.05$) between low and high frequency collision zones. However, all percentage variables were first arcsine transformed ($\arcsin(\sqrt{p})$; p is the proportion of the variable concerned) (Sokal & Rohlf, 1995). The other variables (ROADS_GIS through DIVERSITY_GIS) did not require transformation.

5.2.6. Analyses for Field Observation Data

The team compared the road-, traffic and landscape variables obtained through direct field observations (Table 5-4) between low and high frequency collision zones to identify parameters that may be positively or negatively associated with white-tailed deer-vehicle collisions.

All P-variables (presence) were summarized for each low and high frequency collision zone. If the characteristic was "present" in one of the 0.1 mile road length units of a collision zone then the value for that entire collision zone was set at "1". If the characteristic was not present in any of the 0.1 mile long road length units of a collision zone, the value was set at "0". The same procedure applied to the O-, G- and S-variables (orientation, presence of grass, presence of shrubs), but only if the landscape feature concerned was present (P-variable). If the landscape feature concerned was not present, then the O-, G- and S-variables were left blank ("not applicable").

All values of the D-, Q-, and W-variables (distance, quantity and width), VEHICLES, and SPEED were averaged for each collision zone. The different categories for LANDSCAPE, FOREST_TYPE, FOREST_BURN, and FOREST_CUT were split into separate variables and then their relative abundance (%) for each collision zone was calculated.

Researchers calculated the mean of all variables for low and high collision zones, using chi^2 tests (Pearson statistic) to test for possible differences ($P<0.05$) between low and high frequency collision zones for all P-, O-, G- and S- variables. T-tests were used to test for possible differences ($P<0.05$) between low and high frequency collision zones for all other variables. However, all percentage variables, i.e. all Q-variables and the variables derived from the different categories for LANDSCAPE, FOREST_TYPE, FOREST_BURN, and FOREST_CUT, were first arcsine transformed ($\arcsin(\sqrt{p})$; p is the proportion of the variable concerned) (Sokal & Rohlf, 1995). The other variables did not require transformation.

Before conducting the analyses to investigate which road-, traffic-, and landscape variables may be associated with high frequency white-tailed deer collision zones, WTI investigated potential strong positive or negative correlations ($r \geq 0.80$ or $r \leq -0.80$) between the individual variables. The vast majority of all P- and Q-variables were strongly positively correlated. Most of the P- and D-variables and the D- and Q- variables had strong negative correlation coefficients. These strong correlations were partly due to extreme values (e.g., P=0 then Q=0), or P=0 then D=101, or Q=0 then D=101), and not based on a true correlation over the full range. In addition, SIDE_SIGHT and D_FOREST, SPEED and D_LIGHTS, D_WATER and D_OPEN_WATER, P_WATER and P_OPEN_WATER, Q_WATER and P_OPEN_WATER, Q_WATER and Q_OPEN_WATER, P_HEDGEROW and D_GRASS_ROW, P_GRASS_ROW and D_HEDGEROW, Q_HEDGROW and D_GRASS_ROW, and Q_GRASS_ROW and D_HEDGEROW were all strongly positively correlated. Finally, SPEED and D_LIGHTS, SPEED and Q_LIGHTS, Q_WATER and D_OPENWATER, D_HEDGE and D_GRASS_ROW, P_HEDGEROW and P_GRASS_ROW, Q_HEDGEROW and P_GRASS_ROW, Q_GRASS_ROW and P_HEDGEROW were all strongly negatively correlated.

5.3. Results

5.3.1. Results for GIS data

Table 5-6, Table 5-7 and Table 5-8 show the results for the GIS variables for the 1000, 500 and 100 m buffer zones. Most GIS landscape variables had similar values for low and high frequency collision zones for the three buffer zones. However, there was significantly more forest edge (FOREST_EDGE_GIS) in high collision zones (30.21 m/ha) than in low collision zones (21.70 m/ha) for the 1000 m buffer zone (P=0.014; 1-tailed t-test) (Table 5-6). The same was true for the 500 m buffer zone: 37.75 m/ha forest edge in high frequency collision zones and 26.04 m/ha in low frequency collision zones (P=0.018; 1-tailed t-test) (Table 5-7). There was also more forest edge in high collision zones (56.43 m/ha) than in low collision zones (35.37 m/ha) for the 100 m buffer zone (P=0.015; 1-tailed t-test) (Table 5-8). In addition, high frequency collision zones had more shrubland (SHRUBLAND_GIS), higher landscape heterogeneity (HETEROGENITY_GIS) and higher landscape diversity (DIVERSITY_GIS) than low frequency collision zones (P-values all ≤ 0.05) (Table 5-8).

Table 5-6: The mean values for each GIS variable for the low and high frequency collision zones with 1000 m buffer zone (t-tests).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
FOREST_GIS (%)	65.95	65.67	0.890
OPEN_FOREST_GIS (%)	2.44	2.00	0.733
SHRUBLAND_GIS (%)	15.29	8.59	0.094
CLEARED_GRASS_GIS (%)	6.86	10.75	0.228
ARABLE_LAND (%)	4.82	5.76	0.942
BUILT-UP_GIS (%)	0.76	0.93	0.468
WATER_GIS (%)	3.88	6.31	0.357
WATER_WETLAND_GIS (%)	6.20	7.29	0.597
ROADS_GIS (m/ha)	11.22	11.99	0.746
RIVERS_GIS (m/ha)	7.79	6.57	0.603
FOREST_EDGE_GIS (m/ha)	30.21	21.70	0.014*[1]
HETEROGENITY_GIS (m/ha)	105.41	91.60	0.286
DIVERSITY_GIS	0.79	0.75	0.657

*[1] = P-value is for one sided test (see Table 5.3).

Table 5-7: The mean values for each GIS variable for the low and high frequency collision zones with 500 m buffer zone (t-tests).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
FOREST_GIS (%)	64.33	62.84	0.937
OPEN_FOREST_GIS (%)	1.20	2.18	0.486
SHRUBLAND_GIS (%)	14.92	12.84	0.104
CLEARED_GRASS_GIS (%)	9.67	12.53	0.625
ARABLE_LAND (%)	4.08	6.06	0.694
BUILT-UP_GIS (%)	1.29	1.66	0.571
WATER_GIS (%)	4.50	6.88	0.530
WATER_WETLAND_GIS (%)	6.42	7.83	0.582
ROADS_GIS (m/ha)	11.76	13.13	0.650
RIVERS_GIS (m/ha)	8.09	7.45	0.798
FOREST_EDGE_GIS (m/ha)	37.75	26.04	0.018*[1]
HETEROGENITY_GIS (m/ha)	133.80	107.30	0.139
DIVERSITY_GIS	0.77	0.74	0.787

*[1] = P-value is for one sided test (see Table 5.3).

Table 5-8: The mean values for each GIS variable for the low and high frequency collision zones with 100 m buffer zone (t-tests).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
FOREST_GIS (%)	54.58	62.23	0.386
OPEN_FOREST_GIS (%)	0.00	0.32	n/a*[1]
SHRUBLAND_GIS (%)	16.32	6.40	0.041
CLEARED_GRASS_GIS (%)	17.72	19.12	0.917
ARABLE_LAND (%)	4.12	5.78	0.657
BUILT-UP_GIS (%)	4.06	4.09	0.558
WATER_GIS (%)	3.20	2.07	0.414
WATER_WETLAND_GIS (%)	5.31	2.95	0.272
ROADS_GIS (m/ha)	11.75	11.99	0.946
RIVERS_GIS (m/ha)	3.74	4.98	0.558
FOREST_EDGE_GIS (m/ha)	56.43	35.37	0.015*[2]
HETEROGENITY_GIS (m/ha)	216.30	156.00	0.019*[2]
DIVERSITY_GIS	0.82	0.61	0.024*[2]

*[1]= not applicable, no variability for at least one of the two collision zones, test not applicable; *[2]= P-value is for one-sided test (see Table 5.3).

5.3.2. Results for Field Observation Data

Table 5-9 through Table 5-14 show the results for the road-, traffic-, and landscape variables measured through direct field observations. Most of the road-, traffic-, and landscape variables were similar for low and high frequency collision zones.

The presence of edge habitat (EDGE_HABITAT) was higher in high frequency collision zones (76.92%) than in low frequency collision zones (46.67%) (P=0.011; chi^2 tests (Pearson statistic), 1-sided test) (Table 5-11). The quantity of edge habitat present along the road was also higher in high frequency collision zones (9.19%) than in low frequency collision zones (4.14%) (P=0.026; 1-tailed t-test) (Table 5-12). In addition, edge habitat was closer to the edge of the pavement in high frequency collision zones (72.58 m) than in low frequency collision zones (85.82 m) (P=0.029; 1-tailed t-test) (Table 5-13). Tree lines (TREE_LINE) represent a form of edge habitat, and they were also closer to the edge of the pavement in high frequency collision zones (86.69 m) than in low frequency collision zones (97.06 m) (P=0.043; 1-tailed t-test) (Table 5-13).

The presence, quantity and orientation of riparian habitat (RIPARIAN) was similar for low and high frequency collision zones. However, riparian habitat was closer to the edge of the pavement in high frequency collision zones (84.46 m) than in low frequency collision zones (93.80 m) (P=0.037; 1-tailed t-test) (Table 5-13) .

The presence of buildings (BUILDINGS) tended to be higher in high collision zones (80.77%) than in low collision zones (56.66), but the difference was marginally insignificant (P=0.051; chi^2 tests (Pearson statistic), 1-sided test) (Table 5-11). However, the quantity of buildings present along the road was significantly higher in high collision zones (14.16%) than in low collision zones (7.22%) (P=0.021; 2-tailed t-test) (Table 5-12). In addition, buildings were closer to the edge of the pavement in high collision zones (67.60 m) than in low collision zones (82.56 m) (P=0.022; 2-tailed t-test) (Table 5-13). These values related mostly to forest landscapes (see Table 5-10) and not to residential landscapes as there were no high collision zones present in residential landscapes (Table 5-10).

The quantity of guard rail (GUARD_RAIL) present along the road tended to be lower in high collision zones (1.21%) than in low collision zones (6.54%), but this difference was marginally insignificant (P=0.068; 2-tailed t-test) (Table 5-12).

The tests for the possible effect of the perpendicular orientation of linear landscape elements were either not applicable or the test results were unreliable. Some of the variables showed no variation; i.e. the orientation of the landscape elements was always parallel or always perpendicular to the road, leaving no variation and making any test not applicable. Other variables had very low frequencies (N≤5) for at least one of the categories, making chi^2 tests (Pearson statistic) unreliable.

Table 5-9: The mean values for road- and traffic related variables for the low and high frequency collision zones (t-tests). Depending on the variable the values relate to the average number, width, speed or distance for the collision zones.

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
VEHICLES (N)	1509	1370	0.193
ROAD_WIDTH (m)	7.12	7.25	0.514
GRASS_ROW_WIDTH (m)	17.01	16.65	0.829
MOWN_ROW _WIDTH (m)	5.00	5.21	0.753
SPEED (mi/hr)	69.97	68.47	0.201
ROAD_SIGHT (m)	282.60	256.10	0.455
SIDE_SIGHT (m)	11.62	14.21	0.388

Table 5-10 reflects the mean values for the variables derived from the landscape type (LANDSCAPE), forest type (FOREST_TYPE), and burned (FOREST_BURN) and cut forest (FOREST_CUT), for the low and high frequency collision zones, recorded through direct field observations (t-tests). The values relate to the average percent of the road length units within the low or high frequency collision zones that the landscape type or forest type concerned, or for which burned forest or cut forest was present.

Table 5-10: The mean values for the variables derived from the landscape type (t-tests).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
LANDSCAPE TYPES			
FOREST (%)	83.33	84.17	0.923
PRAIRIE (%)	7.53	6.67	0.940
WETLAND (%)	0.68	0.00	n/a*1
AGRICULTURE (%)	8.46	6.67	0.761
RESIDENTIAL (%)	0.00	2.50	n/a*1
FOREST TYPES			
PINE FOREST (%)	43.83	47.94	0.589
DECIDIOUS FOREST (%)	0.00	0.00	n/a*1
MIXED FOREST (%)	56.17	48.72	0.408
BURNED FOREST (%)	0.00	0.00	n/a*1
CUT FOREST (%)	8.01	11.26	0.566

*1 = no variability for at least one of the two collision zones, test not applicable.

Table 5-11 reflects the mean values for the P-variables (presence), for the low and high frequency collision zones, recorded through direct field observations. The values relate to the percent of the collision zones in which the road- and landscape features were present.

Table 5-11: The mean values for the P-variables (presence) for the low and high frequency collision zones recorded through direct field observations (chi^2 tests) (Pearson statistic).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
PASSAGE (%)	3.85	6.67	0.640*1
FOREST (%)	100.00	96.67	0.348*1
GRASS_FOREST (%)	100.00	96.66	0.261*1
SHRUB_FOREST (%)	73.08	76.67	0.757
BARRIER (%)	11.54	0.00	0.056*1
GUARD_RAIL (%)	26.92	30.00	0.799
FENCE (%)	26.92	16.67	0.351
ROAD (%)	84.62	86.67	0.827*1
LIGHTS (%)	7.69	10.00	0.763*1
GRASSLAND (%)	61.54	50.00	0.386
GRASS_ROW (%)	100.00	100.00	n/a*1,2
ARABLE (%)	15.38	13.33	0.827*1
BUILDINGS (%)	80.77	56.66	0.051
GREEN (%)	46.15	30.00	0.213
EDGE_HABITAT (%)	76.92	46.67	0.011*3
TREE_LINE (%)	30.77	20.00	0.353
HEDGEROW (%)	3.85	6.67	0.640*1
RIPARIAN (%)	46.15	30.00	0.213
SLOPE (%)	30.77	46.67	0.224
GULLY (%)	7.69	10.00	0.763*1
RIDGE (%)	7.69	3.33	0.470*1
OPEN WATER (%)	23.08	26.67	0.757
WATER (%)	38.46	36.67	0.890

*1 = one or more of the frequencies are ≤5; test result is not reliable.

*2 = no variability for the two collision zones, test not applicable. *3 = P-value is for one-sided test (see Table 5.4).

Table 5-12 refers to the mean values for the Q-variables (quantity), for the low and high frequency collision zones, recorded through direct field observations. The values relate to the average percent of road length in which the road- and landscape features were present.

Table 5-12: The mean values for the Q-variables (quantity) for the low and high frequency collision zones recorded through direct field observations (t-tests).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
FOREST (%)	85.60	80.7	0.614
BARRIER (%)	0.25	0.00	n/a*1
GUARD_RAIL (%)	1.21	6.54	0.068
FENCE (%)	1.17	0.60	0.339
ROAD (%)	3.72	7.00	0.334
LIGHTS (%)	0.38	2.35	0.461
GRASSLAND (%)	15.66	14.50	0.830
GRASS_ROW (%)	97.25	94.45	0.704
ARABLE (%)	7.74	5.88	0.679
BUILDINGS (%)	14.16	7.22	0.021
GREEN (%)	3.02	2.16	0.403
EDGE_HABITAT (%)	9.19	4.14	0.026*2
TREE_LINE (%)	3.54	0.74	0.151
HEDGEROW (%)	0.03	0.08	0.601
RIPARIAN (%)	5.71	2.41	0.134
SLOPE (%)	9.68	9.07	0.832
GULLY (%)	0.10	1.35	0.313
RIDGE (%)	0.47	0.05	0.313
OPEN WATER (%)	6.51	4.52	0.743
WATER (%)	7.76	5.04	0.524

*1 = no variability for at least one of the two collision zones, test not applicable.

*2 = P-value is for one-sided test (see Table 5.4).

Table 5-13 refers to the mean values for the D-variables (distance) for the low and high frequency collision zones, recorded through direct field observations. The values relate to the average shortest possible distance between the edge of the pavement and the road- or landscape feature concerned.

Table 5-13: The mean values for the D-variables (distance) for the low and high frequency collision zones recorded through direct field observations (t-tests).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
FOREST (m)	13.95	16.65	0.509
BARRIER (m)	100.10	101.00	n/a*1
GUARD_RAIL (m)	90.64	83.64	0.379
FENCE (m)	95.46	98.60	0.259
ROAD (m)	35.34	41.93	0.493
LIGHTS (m)	100.20	98.23	0.438
GRASSLAND (m)	68.44	76.59	0.345
GRASS_ROW (m)	0.12	1.19	0.236
ARABLE (m)	89.52	92.36	0.682
BUILDINGS (m)	67.60	82.56	0.022
GREEN (m)	89.39	92.45	0.491
EDGE_HABITAT (m)	72.58	85.82	0.029*2
TREE_LINE (m)	86.69	97.06	0.043*2
HEDGEROW (m)	100.7	99.75	0.332
RIPARIAN (m)	84.46	93.80	0.037*2
SLOPE (m)	83.43	80.40	0.718
GULLY (m)	100.40	97.51	0.308
RIDGE (m)	98.68	100.50	0.350
OPEN WATER (m)	91.13	95.42	0.426
WATER (m)	86.38	93.34	0.223

*1 = no variability for at least one of the two collision zones, test not applicable.

*2 = P-value is for one-sided test (see Table 5.4).

Table 5-14 refers to the mean values for the O-variables (orientation), recorded through direct field observations. The means relate to the percent of the low or high frequency collision zones in which the feature was oriented perpendicular to the road rather than more parallel. Note, the O-variables were only recorded when the landscape feature concerned was present. If the landscape feature was not present the value for the O-variable was left blank ("not applicable").

Table 5-14: The mean values for the O-variables (orientation) recorded through direct field observations (chi^2 tests (Pearson statistic)).

Variable	High collision zone	Low collision zone	P-value (2-sided unless specified)
BARRIER (%)	0.00	0.00	n/a*1
GUARD_RAIL (%)	0.00	0.00	n/a*1
FENCE (%)	85.71	100.00	0.377*2
ROAD (%)	100.00	92.31	0.184*2
GRASS_ROW (%)	0.00	3.33	0.853*2
EDGE_HABITAT (%)	70.00	78.57	0.577*2
TREE_LINE (%)	12.50	33.33	0.347*2
HEDGEROW (%)	100.00	50.00	0.386*2
RIPARIAN (%)	25.00	33.33	0.676*2
SLOPE (%)	0.00	0.00	n/a*1
GULLY (%)	0.00	0.00	n/a*1
RIDGE (%)	50.00	0.00	0.386*2
OPEN WATER (%)	0.00	0.00	n/a*1

*1 = no variability for the two collision zones, test not applicable.
*2 = one or more of the frequencies are ≤5; test result is not reliable.

5.4. Discussion

High frequency white-tailed deer collision zones along MT 83 are associated with the presence, the amount and the proximity of edge habitat. This does not only apply to areas immediately adjacent to the road, i.e. within the first 100 m, but also to zones that extend much further from the road, i.e. up to 500 or 1000 m. The presence and amount of edge habitat at any distance from the road may allow for relatively high white-tailed deer population density. Edge habitat that is relatively close to the road may also bring animals to the road edge where they will have a higher risk of being involved in a deer-vehicle collision if they decide to cross the road or be on the road surface. High frequency collision zones along MT 83 are also associated with relatively high heterogeneity and diversity of the landscape, and the proximity of riparian habitat within a 100 m zone from the road. All of these parameters (edge habitat, landscape heterogeneity, landscape diversity, riparian habitat) have also been identified in other studies that investigated the habitat use of white-tailed deer and landscape features that may be associated with high frequency white-tailed deer collision zones (Puglisi *et al.*, 1974; Mundinger, 1979; Leach, 1982; Arno *et al.*, 1987; Leach & Edge, 1994; Finder *et al.*, 1999; Nielsen *et al.*, 2003; Rogers, 2004). The amount of shrubland was also associated with high frequency white-tailed deer collisions. Shrublands are likely to provide white-tailed deer with an attractive food source (leaves within reach), but most of the shrublands in the Seeley-Swan valley also seem to be concentrated along the riparian corridors which are an attractant to white-tailed deer.

High frequency white-tailed deer collision zones along MT 83 are also associated with the amount and the proximity of buildings. This seems to contrast with the findings of Nielsen *et al.* (2003) who found that buildings were negatively associated with deer-vehicle collisions sites. However, Nielsen *et al.* (2003) conducted their study in a mostly residential landscape, whereas these data mostly apply to forested landscapes, and to a lesser extent to prairie and agricultural landscapes; residential landscapes were not represented in the high frequency collision zones.

Interestingly, the presence, amount, and proximity of urban green (gardens and fertilized lawns) were not associated with high frequency collision zones. This suggests that white-tailed deer may have responded to other factors that may be correlated to the amount and proximity of buildings. Traffic volume was similar for the high and low frequency collision zones, but the average length of the road segments that were assigned the same traffic volume was 9.8 mi (15.8 km), potentially obscuring finer scale variations in traffic volume. Furthermore, the amount and proximity of buildings may increase the heterogeneity and diversity of the landscape. In addition, people that live in these buildings may provide food to the deer either directly or indirectly, for example through the presence of hay in pastures that may have been intended for livestock, or felling trees with lichen (e.g. Hodgman & Bowyer, 1985; Gray & Servello, 1995).

The human disturbance associated with buildings may also provide white-tailed deer with shelter from predators such as mountain lions, wolves and grizzly bears, species that usually avoid humans and associated disturbance (Mace *et al.*, 1996; Brown et al., 1999; Altendorf *et al.*, 2001; Proctor, 2003; Pierce *et al.*, 2004). Finally, people, dogs and cars near houses or on the low volume roads and access roads to these houses may cause the deer to run away at certain times. White-tailed deer that flee away may not pay much attention to MT 83 and the traffic that uses it, and deer that approach the road at high speed may not allow for much driver reaction time, especially not in non-residential zones with relatively high speed limits. The hypotheses with regard to direct and indirect feeding and shelter from predators match local knowledge and experience (see chapter 6).

The amount of guard rail present along MT 83 tended to be lower in high collision zones (1.21%) than in low collision zones (6.54%), but this difference was marginally insignificant. This may be an indication that guard rails increase the barrier effect of roads and that they may discourage white-tailed deer from crossing the road (cf. Carbaugh *et al.*, 1975). However, guard rails are usually placed along steep slopes or open water, places where one may not expect many white-tailed deer to cross in the first place.

The increase in the amount of forest edge habitat and the increase in landscape heterogeneity from zones that extend further away from MT 83 to zones immediately adjacent to the road, indicate that the zone immediately adjacent to MT 83 is a more attractive habitat to white-tailed deer than areas further away from the road, potentially as the result of human activities along the transportation corridor. This matches local knowledge and experience (see chapter 6).

5.5. Conclusion

White-tailed deer-vehicle collisions along MT 83 are associated with edge habitat, landscape heterogeneity, landscape diversity, riparian habitat, shrubland and buildings. Transportation planners could choose to alter the landscape in a zone adjacent to the road (e.g. up to 100 m from the road) to reduce white-tailed deer movements across selected sections of MT 83. However, in order to avoid isolating individuals and populations on either side of the road, other road sections that have been mitigated for animal-vehicle collisions, e.g. through wildlife fencing in combination with underpasses or overpasses, should have surroundings that encourage white-tailed deer to approach and cross the road.

Naturally, potential changes in the landscape surrounding MT 83 should be carefully evaluated before they are carried out. In areas that have already received heavy human impact (e.g. in agricultural landscapes or clear cuts), landscape changes may be an option, whereas relatively undisturbed areas should preferably be left intact. In addition, potential changes to the landscape surrounding the road may be motivated by the goal to substantially reduce white-tailed deer-vehicle collisions along MT 83, but they should be based on a multi-species or ecosystem approach, as these changes to the landscape should not affect other species, especially those who may be threatened or endangered already. Finally, potential changes in the landscape surrounding MT 83 need to be coordinated and agreed upon with local landowners and users.

As indicated above, the results of this study may be used to make certain changes to the landscape surrounding the road. However, the findings may also be used in the discussion on future activities and developments along the transportation corridor.

6. EXPERT BASED ANIMAL-VEHICLE COLLISION AND HABITAT LINKAGE ZONES

6.1. Introduction

In Chapter 4 high frequency collision zones were identified based on deer carcass and animal-vehicle collision data provided by the Montana Department of Transportation (MDT) and law enforcement agencies (MHP). However, the data sets do not contain all known animal-vehicle collision locations. Therefore individuals with local knowledge and experience (Appendix A) were interviewed (July-August 2004) and asked to identify road sections with a high frequency of animal-vehicle collisions. They were also asked to name animal species for which the current level of habitat connectivity should be maintained or improved and to identify road sections where animals are known to cross the road frequently, regardless of whether these animals may be hit by traffic. These crossing zones may be important habitat linkage areas for certain species and potential future mitigation measures that aim to avoid or reduce animal-vehicle collisions for ungulates should not negatively affect habitat connectivity for those other species.

6.2. Target Species

Individuals with local knowledge and experience (Appendix A) identified two species for which the current level of habitat connectivity should be maintained (Table 6-1) and ten species or species groups for which it should be improved (Table 6-2). The latter group includes several carnivores that are relatively vulnerable to habitat fragmentation. These species or species groups may also act as an "umbrella species" for other species and species groups (Bud Moore). It is also important to pay attention to aquatic species, since potential mitigation measures for animal-vehicle collisions may include the upgrading of stream culverts to underpasses with banks on either side of the stream. A species and site specific analyses should be undertaken to ensure that the potential removal of a barrier for fish (e.g. bull trout) is indeed desirable and does not lead to undesirable side effects such as increased competition or hybridization with non-native species.

Table 6-1 Species for which the current level of habitat connectivity should be maintained

Species name	Source
Elk (*Cervus elaphus*)	Jamie Jonkel
Deer (*Odocoileus sp.*)	Jamie Jonkel

Table 6-2 Species for which the current level of habitat connectivity should be improved.

Species name	Source
Bull trout (*Salvelinus confluentus*)	Jamie Jonkel
Amphibians	Mike Thompson
Small mammals	Mike Thompson
Beaver (*Castor canadensis*)	Bud Moore
Fisher (*Martes pennanti*)	Bud Moore, Mike Thompson, Scott Tomson
Wolverine (*Gulo gulo*)	Bud Moore, Scott Tomson
Elk (*Cervus elaphus*)	Scott Tomson
Canada lynx (*Lynx canadensis*)	Anne Dahl, Jamie Jonkel, Bud Moore
Mountain lion (*Felis concolor*)	Anne Dahl
Black bear (*Ursus americanus*)	Bud Moore
Grizzly bear (*Ursus arctos*)	Anne Dahl, Jamie Jonkel, Bud Moore, Scott Tomson

6.3. Animal-Vehicle Collision and Habitat Linkage Zones

Individuals with local knowledge and experience (Appendix A) identified 76 road sections (Appendix D and E) known for their high frequency of animal vehicle collisions and animal crossings. In some cases important wildlife habitat was marked as well. The road sections were marked with colored ovals on 1:24,000 topographic maps (Appendix D). The colors of the ovals represent different categories of animal habitat, high frequency animal crossing areas and high frequency animal-vehicle collision areas (Table 6-3).

Table 6-3 Categories and color coding of the ovals on the topographic maps (Appendix D).

Category	Color on maps
Important habitat away from MT 83	green
Important habitat adjacent to, or on both sides of MT 83	yellow
High frequency crossing area for small species (up to deer size)	light orange
High frequency crossing area for large species (deer size and up)	dark orange
High frequency collision area for small species (up to deer size)	light red
High frequency collision area for large species (deer size and up)	dark red

If an area marked by an oval qualified for two different categories the color coding for the "worst" category was used. For example, if an area qualified as a high frequency crossing area for large species (dark orange) and also as a high frequency collision area for large species (dark red), then the area was marked with the color that related to the "worst" category (= dark red).

Figure 6-1 gives an overview of the location and name of the 17 different maps in Appendix D.

Figure 6-1 Numbers and names of the 1:24,000 topographic maps in Appendix D.

6.4. Discussion

The areas marked on the 1:24,000 topographic maps (Appendix D) cover almost the entire transportation corridor. This indicates that there are many high frequency collision and animal crossing zones along MT 83. The description of the marked areas (Appendix E) provides more detailed insight in the specific issues for each of these areas. Many of the high frequency collision zones relate to white-tailed (*Odocoileus virginianus*) or mule deer (*O. hemionus*). In winter white-tailed deer road kill are more or less confined to their known wintering areas, but in summer white-tailed deer road kill occurs almost everywhere (Glen Gray, Mike Thompson) (see Appendix A). White-tailed deer show seasonal migration between high elevation areas and the north-east upper Swan. The migration corridors in the Swan valley run north-south, parallel to road (Glen Gray). As a consequence white-tailed deer cross MT 83 frequently.

Comparison of the expert based identification of high frequency collision zones with the MDT data sets suggests that certain species and species groups are systematically underrepresented in the MDT data sets. The MDT data set for the central section contains data for "deer" (*Odocoileus sp.*) only, but the data sets for the southern and northern section do include other large mammal species (see chapter 6). Nevertheless, elk (*Cervus elaphus*) and relatively rare large carnivores such as bears (*Ursus sp.*) seem to be underrepresented in these data sets. For example, only four elk carcasses have been reported between 1998 and 2003 (MDT), three of them in the elk wintering area at Blanchard Flats and south of Salmon Lake (map 1-2; Woodworth, Salmon Lake), whereas this area as well as other areas along MT 83 are known for their concentration of road killed elk. A collision with a large ungulate, e.g. elk or moose (*Alces alces*), is more likely to result in human injuries and human fatalities than a collision with a deer.

Personnel from law enforcement agencies, and perhaps also from natural resource management agencies, are likely to investigate and report an accident that involves human injuries and human fatalities and may then remove the animal carcass before MDT is able to report it. This may explain why relatively few carcasses of large ungulates, larger than deer, are reported by MDT. Carcasses of relatively rare species (e.g. bears, Canada lynx (*Lynx canadensis*) mountain lions (*Felis concolor*), eagles) are also likely to be quickly removed by personnel from natural resource management agencies or other individuals.

Deer (*Odocoileus sp.*) are attracted to the river and wetlands along MT 83 (Chuck McCleod, Tom Parker). In addition, deer are attracted to hay in the horse pastures along the transportation corridor (Ken Wolff). Some people provide food (hay, grain, salt licks) specifically for the deer (Bruce Friede, Tom Parker, Ken Wolff). Furthermore, logging activities along the transportation corridor provide a temporary source of food; lichen from fallen trees (Bruce Friede). A golf course around RP 13 is also thought to be an important attractant for deer (Bruce Friede). Deer appear to have benefited from human- induced changes in the landscape along the transportation corridor. As a result the population size of the deer in the valley may have increased. Alternatively the deer may have simply concentrated along MT 83 because of food availability and relatively low predator numbers (especially wolf (*Canis lupus*)) (Bud Moore, Tom Parker, Scott Tomson). In addition, at least part of the white-tailed deer population is thought to have abandoned seasonal migration and is now present along the transportation corridor year-round (Tom Parker, Ken Wolff).

Clear cuts, thinning, and the removal of undergrowth have affected thermal cover and food availability for deer and other animals in the Seeley-Swan Valley (Bruce Friede). This applies to ungulates as well as carnivores, e.g. through the availability of small mammals and other prey species (Bill Bartlett). Vegetation cover also affects snow depth on the ground which in turn influences animal movements and access to food in winter. Subdivisions and associated disturbance by humans also affect animal distribution and movement patterns. The land use and management has been intensified in the Seeley-Swan valley over the past decade and the abovementioned activities are thought to have changed historical animal distribution and movement patterns considerably (Anne Dahl, Bruce Friede, Glen Gray, Jay Haveman, Tom Parker, Ken Wolff). Therefore the areas identified on the maps (Appendix D) may reflect where animals were killed and used to cross MT 83 rather than where they do so now (Tom Parker).

Grizzly bears (*U. arctos*) and elk in the valley seem to have increased in recent years. Road closure and road removal in certain areas may have been a factor in this development (Glen Gray). Black bears (*Ursus americanus*), grizzly bears, turkey vultures (*Cathartes aura*), golden eagles (*Aquila chrysaetos*), bald eagles (*Haliaeetus leucocephalus*), and common ravens (*Corvus corax*) are known to feed on deer carcasses on and alongside MT 83 (Bruce Friede, Jamie Jonkel, Bud Moore, Tom Parker, Ken Wolff). Consequently some scavenging individuals are killed by traffic. In winter eagles seem especially vulnerable (Bruce Friede). The abundance of deer carcasses and dead fish in drying artificial ponds seem to have triggered golden eagles (8-10 years ago) and turkey vultures to start breeding in the valley (Ken Wolff).

Other road-killed species or species known to go under or across MT 83 are bull trout (*Salvelinus confluentus*), turtles, wild turkey (*Meleagris gallopavo*), beaver (*Castor canadensis*), snowshoe hare (*Lepus americanus*), pine marten (*Martes americana*), mink (*Mustela vison*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), river otter (*Lutra canadensis*), bob cat (*Lynx rufus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and wolf. Ridges, riparian zones, and areas where the road crosses creeks seem to be especially important for a wide range of species and a variety of movement types (daily, seasonal, dispersal), and in some cases these areas are also a known high-frequency collision area (Jamie Jonkel, Tom Parker, Ken Wolff). Larger lakes such as the “chain lakes” funnel wildlife movements through the narrow land sections (Jamie Jonkel).

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

In this report WTI presented the results of the first phase of a site- and species specific mitigation plan. It was aimed at acquiring information and at identifying potential additional research and resource needs. With this information, species- and site-specific mitigation strategies and options will be formulated (phase 2), and phase 3 is aimed at consensus building with natural resource management agencies and the local community. This should ultimately lead to a concrete and effective implementation plan that has broad support (Phase 4). Although the final integration of the information will take place in the next phase (phase 2) the most important conclusions of the four tasks of phase 1 are listed below.

7.1.1. Task 1: Identify and Rank High-Frequency Zones for Animal-Vehicle Collisions

- The number of recorded wildlife-vehicle collisions on MT 83 is 2.8 times that of the state average for this road type. In addition, 26.1% of all road accidents on MT 83 involve wildlife, while the state average is 17.2% for this road type.
- Animal-vehicle collision data from the Montana Department of Transportation (MDT) showed that 94.5% of all reported road-killed animals along MT 83 are white-tailed deer (*Odocoileus virginianus*).
- Animal-vehicle collision data reported by the Montana Department of Transportation (MDT) and law enforcement agencies (Montana Highway Patrol (MHP)) show that animal-vehicle collisions, especially with white-tailed deer, occur along almost the entire length of MT 83. This was confirmed by individuals with local knowledge and experience (see task 4).
- Animal-vehicle collision data from law enforcement agencies (Montana Highway Patrol (MHP)) suggest that animal-vehicle collisions along MT 83 have increased between 1993 and 2000 and then stabilized at a similar or slightly lower level.
- The MDT datasets for the southern (RP 0.0-47.8) and northern section (RP 80.0-91.1) and the MHP dataset (entire route) contained data for 6 and 14 years respectively and had relatively high spatial resolution (0.1 mile). The MDT dataset for the central section (RP 47.8-80.0) only contained road-kill data for two years, did not distinguish between white-tailed deer and mule deer, and had limited spatial resolution (1.0 mile rather than 0.1 mile).
- Despite differences between the data sets and their limitations, the MDT and MHP data sets all qualified as "monitoring data" with consistent search and reporting effort for individual road sections rather than "incidental observations". Note, for the analysis in this study the data needed to be based on consistent search and reporting effort on well defined road sections, but the data sets did not need to include all or most road-killed animals or animal-vehicle accidents.
- Certain sections of MT 83 have a higher frequency of white-tailed deer or deer (*Odocoileus sp.*) collisions than other sections. Based on the MDT dataset, researchers

identified 27 road sections along MT 83 with a relatively high frequency of white-tailed deer-vehicle collisions. Of these 27 road sections 17 had least partial overlap with high frequency collision road sections identified based on the MHP dataset. Mitigation measures aimed at avoiding or reducing animal-vehicle collisions (or white-tailed deer-vehicle collisions, specifically) should prioritize these road sections above others. Note: the spatial resolution for high frequency "deer" collision zones in the central section (RP 47.8-80.0) was relatively coarse (1.0 mile) compared to that for the southern (RP 0.0-47.8) and northern section (RP 80.0-91.1).

7.1.2. Task 2: Identify Road and Landscape Characteristics Associated With Animal-Vehicle Collisions

- White-tailed deer collision zones along MT 83 are associated with edge habitat, riparian habitat, shrubland, buildings, and relatively high landscape heterogeneity and landscape diversity in a 100 m wide zone on either side of the road.
- White-tailed deer collision zones along MT 83 are also associated with edge habitat in a zone adjacent to the road that extends up to 500 and 1000 m from either side of the road.
- The landscape characteristics of high frequency white-tailed deer collision zones mentioned above may further help identify and prioritize locations along MT 83 that require mitigation for white-tailed deer-vehicle collisions. The findings may also lead to a discussion on the current and future habitat, land use and land management in a zone adjacent to MT 83 and how this may ensure the long term effectiveness of potential mitigation measures.

7.1.3. Task 3: Identify and Rank (Additional) Habitat Linkage Zones

- Comparison of the animal-vehicle collision data reported by MDT with expert based identification of high-frequency collision areas suggests that large ungulates other than deer, e.g. elk (*Cervus elaphus*) and relatively rare carnivores, e.g. grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), mountain lions (*Felis concolor*), Canada lynx (*Lynx canadensis*), are underrepresented in animal-vehicle collision data collected by MDT and law enforcement agencies (MHP). Carcasses of relatively small species, e.g. amphibians, turtles, pine marten (*Martes americana*), fisher (*Martes pennanti*), golden eagle (*Aquila chrysaetos*), and bald eagle (*Haliaeetus leucocephalus*), are not recorded by MDT. While the smaller species are mostly a conservation concern, the larger species, especially the relatively abundant elk, are also a safety concern.
- Individuals with local knowledge and expertise (Appendix A) identified certain sections of MT 83 as having a higher frequency of animal crossings than other sections. Mitigation measures aimed at reducing the barrier effect of the road for selected species and reducing potential future animal-vehicle collisions should prioritize these road sections above others. However, additional information may be needed to verify that those locations are indeed high frequency crossing and/or collision areas for the species identified.
- Changes in land use and management and supplementary feeding of wild animals, including deer, are thought to have led to a concentration of deer or a higher deer

population size along MT 83. In addition, at least part of the white-tailed deer population is thought to have abandoned seasonal migration. The increase in the number of deer present along the transportation corridor and the year-round exposure to traffic is likely to have contributed to an increase in deer-vehicle collisions, especially between 1993 and 1996.

- Changes in land use and management and supplementary feeding of wild animals, including deer, especially over the last decade, are thought to have led to changes in animal distribution and animal movement patterns (daily, seasonal and dispersal). Therefore road sections with a relatively high frequency of animal-vehicle collisions and animal crossings may reflect where animals were killed and used to cross MT 83 rather than where they cross now.

7.1.4. Task 4: Identify and Document Additional Research and Resource Needs

- The central section (RP 47.8-80.0) lacks spatially precise animal-vehicle collision data collected by MDT. The location of road-killed animals was only recorded with 1.0 mile accuracy. To increase the spatial resolution of the high frequency collision zones in the central section, researchers could use the results of chapter 5 (road-, traffic- and landscape characteristics of high frequency white-tailed deer collision zones) to create a predictive model. Note: see also recommendations for future monitoring of road-killed animals (section 7.2.2).
- Additional individuals with local knowledge and experience may need to be interviewed (Appendix F). The list may have to be expanded to include species experts for all the species for which the current level of habitat connectivity should be improved or maintained. These species and species groups include bull trout, amphibians, turtles, small mammals, pine marten, fisher, wolverine, deer, elk, Canada lynx, mountain lion, black bear, and grizzly bear.
- For certain species the available local knowledge may be too limited to reliably identify high frequency collision or crossing zones. If the reduction of animal-vehicle collisions and the improvement of habitat connectivity across MT 83 are considered very important to the long term survival of such a species, spatial modeling of important habitat and habitat linkage zones may be advisable. Field studies on the particular movements and habits of these species in relation to the transportation corridor and landscape features in the Seeley-Swan Valley may also provide valuable information to help guide recommendations. However, it may take many years to answer certain questions through field studies, and the population survival probability of certain species may have dropped below a critical threshold by the time those data may become available.
- WTI also asked individuals with local knowledge and expertise (see Appendix A) about their opinions and ideas on potential additional research and resource needs. These thoughts and comments are listed below. Note: WTI and MDT do not necessarily agree or disagree with these statements. The statements merely reflect the ideas of the people that were interviewed for this report:

- A deer-vehicle collision study would be helpful to put the numbers killed on the road in perspective. More deer may die on the road than through hunting. A more general road-kill study would also help identify locations that may require mitigation measures such as wildlife crossing structures (Anne Dahl Bud Moore, Tom parker).
- The number and location of potential wildlife crossing structures need to be carefully studied, especially since wildlife movements seem diffuse along the entire transportation corridor (Anne Dahl, Jay Kolbe).
- The number and location for potential crossing structures for elk may require more knowledge about their seasonal migration patterns (Jay Haveman, Jay Kolbe).
- Species specific research may be required for wolverines, Canada lynx, and grizzly bears (Scott Tomson).
- Reduced vehicle speed may lead to fewer animal-vehicle collisions. Measures that encourage drivers to reduce vehicle speed may be very effective and should be reviewed (Glen Gray, Jay Kolbe, Joe Lawrence, Scott Tomson, Ken Wolff).
- If extensive wildlife fencing is considered more insight is needed into the negative side effects of fencing (e.g. increased barrier effect of the transportation corridor, birds that may fly against the fence and die) (Anne Dahl, Scott Tomson).
- Monitor the maintenance and effectiveness of potential future mitigations measures, especially wildlife crossing structures and wildlife fencing (Mike Thompson, Scott Tomson).

7.2. Recommendations

The research team developed specific recommendations and considerations with regard to further preparations for a site- and species-specific mitigation plan and potential mitigation measures, and the management and future monitoring of road-killed animals and animal-vehicle collisions.

7.2.1. Implementation Plan

- WTI recommends proceeding with further preparations for a site- and species-specific implementation plan to effectively reduce animal-vehicle collisions and improve habitat connectivity for selected animal species along MT 83; i.e.
  - Phase 2: address additional research and resource needs, compile species- and site-specific mitigation strategies and options;
  - Phase 3: consensus building with natural resource management agencies and the local community;
  - Phase 4: a concrete and effective implementation plan that has broad support.
- Outreach and public education throughout the planning process is essential. However, it may be a challenge to persuade certain groups or individuals to participate in the process. A communication plan that recognizes the diversity in the community, and the assistance of a professional consensus builder may be required.

- In addition to the findings of chapter 5 (road-, traffic and landscape characteristics of high frequency white-tailed deer collision zones), a site- and species specific mitigation plan should pay special attention to areas that are close or adjacent to lakes, rivers, creeks or other wetlands. Larger lakes seem to funnel animal movements whereas rivers, creeks and other wetlands seem to be a major attractant to many wildlife species. A wide range of animal species travel along creeks and riparian areas and cross MT 83 at creek crossings. Fish passages and barriers require very careful evaluation as improved habitat connectivity could also expose threatened native species to competition and hybridization with non-native species.
- A site- and species specific mitigation plan should pay special attention to the presence of wildlife trails and documented wildlife crossings. Tom and Melanie Parker of Northwest Connections (see Appendix A) have detailed maps available of wildlife trails and animal crossing areas for selected areas in the valley and along MT 83.
- When one has identified an area that may require mitigation measures, either because of safety or conservation concerns, it is important to investigate whether that area still has a safety or conservation problem or whether the animal distribution and movement patterns have changed, e.g. over the last several years.
- High-frequency animal-vehicle collision and high frequency animal crossing areas are often related to the habitat and land use and management on either side of the road. This has indeed been confirmed for high frequency white-tailed deer collision zones for MT 83 (see chapter 5). Potential mitigation measures, especially wildlife crossing structures, should preferably be based on an integrated approach that includes the traffic, road, right-of-way, and the lands adjacent to the transportation corridor. This may require partnering with natural resource management agencies and private landowners and land users and developing agreements on the zoning of certain activities (e.g. clear cuts, subdivisions, and (motorized) recreation).
- Certain species (e.g. fisher, Canada lynx, grizzly bear) require large areas of suitable habitat with limited human disturbance. Mitigation measures along or adjacent to the transportation corridor can increase the long term population survival probability for certain species, but additional measures away from the road may be required to ensure the long term future of these species in the area.
- Individuals with local knowledge and expertise were interviewed with regard to their ideas and opinions on potential mitigation measures. This information was not included in this report but will be used in a potential phase 2 when a site and species specific mitigation plan is formulated.

7.2.2. Management and Future Monitoring of Animal-Vehicle Collisions

- Continue to collect animal-vehicle collision data as this helps identify road sections that have the highest frequency of animal-vehicle collisions and that may require safety-based mitigation. These data may also serve as baseline data to evaluate the effectiveness of potential future mitigation measures.
- Other organizations and individuals that remove a substantial number of road-killed animals (e.g. deer and elk) or that report and collect relatively rare species (e.g. grizzly

bear, Canada lynx, eagles) may also help collect animal-vehicle collision data. The additional data for certain relatively small species (smaller than deer) help identify road sections that may require conservation-based mitigation while the additional data for relatively large species (deer size and up) help identify road sections that may also require safety-based mitigation. Note: if some organizations or individuals have been removing a substantial number of deer carcasses from certain road sections and not from other road sections, and if these carcasses were not recorded by MDT, then the analyses in chapter 5 that identified road sections with a relatively high 'deer value' may have been at least partially biased.

- Further implement the standardization of animal-vehicle collision data collection within MDT, and coordinate this effort with other organizations and individuals if possible.
- Develop procedures and provide tools that allow for better distinction between incidental observations and monitoring data.
- Develop procedures and provide tools that allow for better quantification of the search and reporting effort of monitoring data.
- Develop procedures and provide tools that allow for better data quality. This relates especially to the spatial accuracy of animal-vehicle collision data (e.g. with GPS units, with or without customized data collection software for pocket PC's). Additional improvements may be made with species identification (e.g. species identification guides), especially with regard to distinguishing between white-tailed and mule deer, and recording whether a carcass was removed.
- Currently not all large road-killed animals are removed from the right-of-way. These carcasses are an attractant to golden eagles and turkey vultures (*Cathartes aura*) which have started to nest in the Seeley Swan valley over the last decade. The abundance of animal carcasses, especially of white-tailed deer, may have been an important factor triggering golden eagles and turkey vultures to nest in this area. In addition, grizzly bears, black bears, bald eagles, and common ravens also frequently feed on animal carcasses on or along the road. Some of these individuals then fall victim to traffic themselves. In winter, eagles seem especially vulnerable. The abundance of road-killed animals seems to lead to additional road-killed animals, especially of scavengers, and some species now partly depend on road-killed animals for food. These facts may initiate a discussion whether all (large) road-killed animals should be removed from the transportation corridor as soon as possible and whether carcasses should be made available to scavengers at other locations.

8. REFERENCES

Altendorf, K.B., J.W. Laundre, C.A. Lopez-Gonzalez, J.S. Brown. 2001. Assessing effects of predation risk on foraging behavior of mule deer. Journal of Mammalogy 82: 430-439.

Arno, S.F., G.E. Gruell, J.G. Mundinger & W. Schmidt. 1987. Developing silvicultural prescriptions to provide both deer winter habitat and timber. Western Wildlands Winter 1987: 19-24.

Baty, G.R. 1995. Resource partitioning and browse use by sympatric elk, mule deer and white-tailed deer on a winter range in western Montana. MSc. Thesis. University of Montana, Missoula, MT, USA.

Baxter, C.V., C.A. Frissell & F.R. Hauer. 1999. Geomorphology, logging roads, and the distribution of bull trout spawning in a forested river basin: Implications for management and conservation. Transactions of the American Fisheries Society 128: 854–867.

Begon, M., J.L. Harper, and C.R. Townsend. 1996. Ecology: Individuals, Populations, and Communities, 3rd edition. Blackwell Science Ltd., Cambridge, MA, USA.

Bellis, E.D. & H.B. Graves. 1971. Collision of vehicles with deer studied on Pennsylvania Interstate road section. Highway Research News 43: 13-16.

Black, A. 2002. Final project report for Swan Valley Conservation Assessment. The Trust for Public Lands. Northern Rockies Field Office, Helena, Montana, USA.

Brewer, C.K., J.A. Barber, G. Willhauck, & U.C. Benz. 2003. Multi-source and multi-classifier system for regional land cover mapping. In: Proceedings of the IEEE Workshop on Advances in Techniques for Analysis of Remotely Sensed Data; NASA Goddard Space Flight Center, Greenbelt MD, Institute of Electrical and Electronic Engineers; Geospatial and Remote Sensing Society.

Brewer, C.K., D. Berglund, J.A. Barber, & R. Bush. 2004. Northern Region Vegetation Mapping Project. Summary Report and Spatial Datasets. Unpublished Report. USDA Forest Service, Northern Region, Missoula Montana. Available from the Internet: http://www.fs.fed.us/r1/gis/ThematicTables.htm#Biology

Brown, J.S., J.W. Laundre & M. Gurung. 1999. The ecology of fear: Optimal foraging, game theory, and trophic interactions. Journal of Mammalogy 80: 385-399.

Burford, D.D. Jr. 2005. An assessment of culverts of fish passage barriers in a Montana drainage using a multi-tiered approach. M.Sc. Thesis. Montana State University, Bozeman, MT, USA.

Cahoon, J., O. Stein, M. Blank, T. McMahon & D. Burford. 2005. Fish passage at road crossings in a Montana watershed. Montana State University, Civil Engineering Department, Bozeman, MT, USA.

Carbaugh, B., J.P. Vaughan, E.D. Bellis & H.B. Graves. 1975. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management 39: 570-581.

Clevenger, A.P., B. Chruszcz, K. Gunson & J. Wierzchowski. 2002. Roads and wildlife in the Canadian Rocky Mountain Parks – movements, mortality and mitigation. Final report to Parks Canada. Banff, Alberta, Canada.

Dunham, J.B. & B.E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic and geometrical landscape characteristics. Ecological Applications 9: 642-655.

ESRI. 1999. ArcView GIS version 3.3. Environmental Systems Research Institute (ESRI). Redlands, California, USA.

Finder, R.A., J.L. Roseberry & A. Woolf. 1999. Site and landscape conditions at white-tailed deer/vehicle collision locations in Illinois. Landscape and Urban Planning 44: 77-85.

Gray, P.B. & F.A. Servello. 1995. Energy intake relationships for white-tailed deer on winter browse diets. Journal of Wildlife Management 59: 147-152.

Gunther, K.A., M.J. Biel & H.L. Robison. 1998. Factors influencing the frequency of road-killed wildlife in Yellowstone National Park. Pp. 32-36. In: G.L. Evink, P. Garrett, D. Zeigler & J. Berry (Eds.). Proceedings of the International Conference on Wildlife Ecology and Transportation. FL-ER-69-98. Florida Department of Transportation, Tallahassee, Florida, USA.

Hodgman, T.P. & R.T. Bowyer. 1985. Winter use of arboreal lichens Ascomycetes by white-tailed deer *Odocoileus virginianus* in Maine USA. Canadian Field Naturalist 99: 313-316.

Huijser, M.P., P.J.M. Bergers & C.J.F. ter Braak. 2000. Road, traffic and landscape characteristics of hedgehog traffic victim sites. Pp. 107-126. In: M.P. Huijser. Life on the edge: Hedgehog traffic victims and mitigation strategies in an anthropogenic landscape. PhD thesis, Wageningen University, Wageningen, The Netherlands.

Huijser, M.P. 2004. Implementation plan for wildlife mitigation measures along highway 83 in the Seeley-Swan Valley, Montana: animal-vehicle collisions and habitat connectivity. Proposal for the Montana Department of Transportation. Western Transportation Institute, Montana State University, Bozeman, MT, USA.

Janke, D. 1977. White-tailed deer population characteristics, movements and winter site selection in Western Montana. Thesis. University of Montana, Missoula, MT, USA.

Keeping the Wild in the West. 2003. High mortality, low reproduction among lynx in northwest Montana. Keeping the Wild in the West, 1 (2): 4. Available from the Internet: http://www.predatorconservation.org/%20Media/PDF/kww_spring_2003.pdf

Kendall, K.C. Unknown. Northern Divide Grizzly Bear Project. Available from the Internet: http://nrmsc.usgs.gov/research/NCDEbeardna.htm

Leach, R.H. 1982. Statewide white-tailed deer ecology studies. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitat in northwestern Montana (Summer range ecology of white-tailed deer in the coniferous forests of northwestern Montana). Thesis. University of Montana, Missoula, MT, USA.

Leach, R.H. & W.D. Edge. 1994. Summer home range and habitat selection by white-tailed deer in the Swan Valley, Montana. Northwest Science 68(1): 31-36.

Mace, R.D, J.S. Waller, T.L. Manley, L.J. Lyon, H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33: 1395-1404.

Mackie, R.J., D.F. Pac, K.L. Hamlin & G.L. Dusek. 1998. Ecology and management of mule deer and white-tailed deer in Montana. Montana Fish, Wildlife and Parks, Helena, MT, USA.

Malo, J.E., F. Suárez & A. Díez. 2004. Can we mitigate animal-vehicle accidents using predictive models? Journal of Applied Ecology 41: 701-710.

Miller, B.K. & J.A. Litvaitis. 1992. Use of roadside salt licks by moose, *Alces alces*, in northern New Hampshire. Canadian Field-Naturalist 106: 112-117.

Montana Department of Transportation. 1998. Special provisions. Contract for Federal Aid Project no. STPP 83-2(7)48. Note: the design was probably prepared in house by the Montana Department of Transportation, MT, USA.

Montana Department of Transportation. 2005. Low volume roads in the Seeley-Swan valley 2005. Obtained from Zia Kazimi, Montana Department of Transportation, Helena, MT, USA.

Montana Department of Transportation. In prep. Safety management manual for the safety engineering improvement program and safety review. Definitions and formula obtained from Tom Hanek, Montana Department of Transportation, Helena, MT, USA.

Mundinger, J. 1978. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitat of northwestern Montana. Pp. 5-80. In: Mackie, R.J. Statewide deer research: job progress report, research project segment. Montana Department of Fish and Game, Helena, MT, USA.

Mundinger, J. 1979. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitat of northwestern Montana. Pp. 5-65. In: Mackie, R.J. (Ed.). Statewide deer research: job progress report, research project segment. Montana Department of Fish and Game, Helena, MT, USA.

Mundinger, J. 1981. White-tailed deer reproductive biology in the Swan Valley, Montana. Journal of Wildlife Management 45 (1): 132-139.

Neraas, L.P. & P. Spruell. 2001. Fragmentation of riverine systems: the genetic effects of dams on bull trout (*Salvelinus confluentus*) in the Clark Fork River system. Molecular Ecology 10, 1153–1164.

Nielsen, C.K., R.G. Anderson & M.D. Grund. 2003. Landscape influences on deer-vehicle accident areas in an urban environment. Journal of Wildlife Management 67: 46-51.

Oregon Dept. of Forestry, 2003. XTools. Also available from the internet. URL: www.odf.state.or.us/DIVISIONS/management/state_forests/XTools.asp Accessed April 2005.

Peek, J.M. 1984. Northern Rocky Mountains. Pp. 497-512. In: L.K. Halls (Ed.).White-tailed deer. Ecology and management. Wildlife Management Institute, Stackpole Books, Harrisburg, PA, USA.

Pierce, B.M., R.T. Bowyer & V.C. Bleich. 2004. Habitat selection by mule deer: Forage benefits or risk of predation? Journal of Wildlife Management 68: 533-541.

Proctor, M.F. 2003. Genetic analysis of movement, dispersal and population fragmentation of grizzly bears in southwestern Canada. Dissertation. The University of Calgary, Calgary, Canada.

Puglisi, M.J., J.S. Lindzey & E.D. Bellis. 1974. Factors associated with highway mortality of white-tailed deer. Journal of Wildlife Management 38: 799-807.

Rogers, E. 2004. An ecological landscape study of deer-vehicle collisions in Kent County, Michigan. White Water Associates, Inc., Amasa, MI, USA.

Ruediger, B., J. Claar, S. Gniadek, B. Holt, L. Lewis, S. Mighton, B. Naney, G. Patton, T. Rinaldi, J. Trick, A. Vandehey, F. Wahl, N, Warren, D. Wenger & A. Williamson. 2000. Canada lynx conservation assessment and strategy. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication #R1-00-53, Missoula, MT, USA.

Seeley Swan Pathfinder. 1996. Grizzly Bear management in Swan Valley. Seeley Swan Pathfinder 25 April 1996. Available from the internet: http://www.seeleyswanpathfinder.com/pfnews/grizzlymeeting.html

Seiler, A. 2003. The toll of the automobile: wildlife and roads in Sweden. PhD thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.

Seiler, A. 2005. Predicting locations of moose-vehicle collisions in Sweden. Journal of Applied Ecology 42: 371-382.

Servheen, C., J.S. Waller & P. Sandstrom. 2003. Identification and management of linkage zones for wildlife between the large blocks of public land in the northern Rocky Mountains. Updated 8 July 2003. U.S. Fish and Wildlife Service, College of Forestry and Conservation, University of Montana, Missoula, Montana, USA.

Slott, B. 1979. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitats of northwestern Montana. Factors affecting deer populations in coniferous forest habitat of western Montana. (White-tailed deer movements, survival, and population characteristics in the Clearwater River drainage, Montana). Thesis. University of Montana, Missoula, MT, USA.

Sokal, R.R. & F.J. Rohlf. 1995. Biometry. The principles and practice of statistics in biological research. 3rd edition. W.H. Freeman and Company, New York, USA.

Squires, J.R. & T. Laurion. 2000. Lynx home range and movements in Montana and Wyoming: preliminary results. Pp. 337-349. In: L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey & J.R. Squires (Eds.). Ecology and conservation of lynx in the United States. University Press of Colorado / Rocky Mountain Research Station, USA.

U.S. Department of the Interior. 1992. Standards for digital orthophotos. U.S. Geological Survey, Reston, VA. Available from the internet: http://geography.wr.usgs.gov/doq/.

U.S. Geological Survey. 1994. Standards for 1:24,000-Scale Digital Line Graphs and Quadrangle Maps: National Mapping Program Technical Instructions. National Mapping Program. Available from the internet: http://nris.state.mt.us/nsdi/drg.html.

Williams, D. 2003. Past and current practices of winter maintenance at the Montana Department of Transportation (MDT). Montana Department of Transportation, December 18, 2001, Updated December 31, 2003. Available from the internet: http://www.mdt.state.mt.us/departments/maintenance/docs/wintmaint_whitepaper.pdf

APPENDIX A: CONTACT DETAILS OF INTERVIEWED INDIVIDUALS

Individuals interviewed or contacted because of their local knowledge and experience with regard to animal occurrence, animal movements and animal-vehicle collisions in the Seeley Swan, especially along MT 83.

Name	Affiliation/profession	Contact details
Bill Bartlett	26 yr resident of Seeley area, logger, hunter, trapper, also works for outfitter	Seeley Lake, MT 59868, 406-677-2119
Anne Dahl	Executive Director Swan Ecosystem Center	6887 Hwy 83, USFS Condon Work Center, Condon, MT 59826, 406-754-3137, swanec@blackfoot.net
Kristi DuBois	Montana Fish, Wildlife & Parks, native species coordinator, Missoula	406-542-5551
Bruce Friede	Montana Department of Transportation, Missoula-Maintenance, Seeley Lake, Hwy 83, RP 0.0-47.8	406-677-2599, bfriede@state.mt.us
Glen Gray	Retired Department of Natural Resources and Conservation, Swan River State Forest supervisor, life-long hunter	56480 Hwy 83 south Swan Lake, MT 59911 406-754-2414
Jay Haveman	Retired Montana Fish, Wildlife & Parks game warden (1973-1995)	PO Box 513, Seeley Lake, MT 59868, 406-677-2231
Bob (Robert) Henderson	Wildlife Biologist, Montana Fish, Wildlife & Parks	406-542-5515
Bert Johnson	Montana Department of Transportation, Kalispell-Maintenance, Bigfork, Hwy 83, RP 80.0-91.1	406-755-2007, wjohnson@state.mt.us
Jamie Jonkel	Montana Fish, Wildlife & Parks, bear management specialist	406-542-5508
Jay Kolbe	Forest Service, Supervisory Biological Science Technician, works for John Squires on lynx and coyote	PO Box 1288, Seeley Lake MT, 59868, jaykolbe@hotmail.com
Joe & Joyce Lawrence	Joe: Born and raised in the upper Swan (near Swan Lake), retired employee of Department of Natural Resources, Swan State Forest, worked for Glen Gray, life-long hunter.	406-886-2259
Tom Litchfield	Biologist, Montana Fish, Wildlife & Parks, Kalispell	406-751-4582
Rick (Richard) Mace	Research Biologist, Montana Fish, Wildlife & Parks, Kalispell	490 North Meridian Road, Kalispell, MT 59901, 406- 751-4583, rmace@state.mt.us

Name	Affiliation/profession	Contact details
Chuck (Charles) Mcleod	Montana Department of Transportation, Kalispell-Maintenance, Swan Lake Hwy 83, RP 47.8-80.0	406-886-2282, chmcleod@state.mt.us
Bud Moore	Retired Forest Service Ranger and former Chief of Fire Management and Air Operations for the Northern Region, Long time resident and logger	PO Box 1070 Condon, MT 59826 406-754-2473
Tom Parker	Outfitter and educator, community involvement, directs research and monitoring programs of Northwest Connections	PO Box 1309 Swan Valley, MT59826, 406-754-3185, nwc@montana.com
John Squires	Research Wildlife Biologist, Rocky Mountain Research Station, USFS	406-542-4164, jsquires@fs.fed.us
Mike (Michael) Thompson	Wildlife biologist, Montana Fish Wildlife & Parks, Clearwater river drainages	406-542-5523
Scott Tomson	Wildlife biologist, National Forest Service, Seeley Lake and Missoula Ranger District, Lolo National Forest	Seeley Lake/Missoula Districts, Building 24, Fort Missoula, Missoula, MT 59805, 406-677-3925, stomson@fs.fed.us
Ken Wolff	Director grounded eagle foundation, runs Northern Rockies Raptor Center, Condon	Grounded Eagle Foundation, inc., 278 Kraft Creek Road, Condon, MT 59826-8801, 406-754-2880, eagleguy@blackfoot.net

APPENDIX B: MDT'S ANIMAL-CARCASS PARAMETERS

FIELD	FORMAT	CODE	VALUE	LENGTH
DATE	DATE			15
LIGHT CONDITION	9	1	DAY	1
		2	NIGHT	
		3	UNKNOWN	
SYSTEM	CHARACTER	I	INTERSTATE	1
		P	PRIMARY	
		S	SECONDARY	
		X	OFF SYSTEM	
ROUTE	999			3
REFERENCE POST	999.999			8
DIRECTION	9	1	EAST	1
		2	WEST	
		3	NORTH	
		4	SOUTH	
		5	UNKNOWN	
ANIMAL	99	1	ANTELOPE	2
		2	BLACK BEAR	
		3	GRIZZLY BEAR	
		4	ELK	
		5	WHITETAIL DEER	
		6	MULE DEER	
		7	MOOSE	
		8	BIGHORN SHEEP	
		9	MOUNTAIN GOAT	
		10	MOUNTAIN LION	
		11	OTHER(WILD)	
		12	OTHER(DOMESTIC)	
		13	DEER(UNKNOWN)	
SEX	9	1	MALE	1
		2	FEMALE	
		3	YEARLING	
		4	UNKNOWN	
COMMENTS	CHARACTER			25

APPENDIX C: CLUSTER CATEGORIES

Southern Section – MDT 0.0 -48.0

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
0.0	0	0	absent
0.1	0	0	absent
0.2	0	0	absent
0.3	0	0	absent
0.4	0	0	absent
0.5	0	0	absent
0.6	0	0	absent
0.7	0	0	absent
0.8	0	0	absent
0.9	0	0	absent
1.0	0	0	absent
1.1	0	0	absent
1.2	0	0	absent
1.3	0	0	absent
1.4	0	0	absent
1.5	0	0	absent
1.6	0	0	absent
1.7	0	0	absent
1.8	0	1	very low
1.9	1	3	high
2.0	2	3	high
2.1	0	2	medium
2.2	0	0	absent
2.3	0	1	very low
2.4	1	2	medium
2.5	1	2	medium
2.6	0	1	very low
2.7	0	2	medium
2.8	2	5	very high
2.9	3	10	very high
3.0	5	14	very high
3.1	6	12	very high
3.2	1	7	very high
3.3	0	1	very low
3.4	0	3	high
3.5	3	4	high
3.6	1	7	very high
3.7	3	8	very high

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
3.8	4	7	very high
3.9	0	7	very high
4.0	3	5	very high
4.1	2	6	very high
4.2	1	8	very high
4.3	5	7	very high
4.4	1	8	very high
4.5	2	7	very high
4.6	4	8	very high
4.7	2	6	very high
4.8	0	3	high
4.9	1	11	very high
5.0	10	12	very high
5.1	1	14	very high
5.2	3	5	very high
5.3	1	4	high
5.4	0	5	very high
5.5	4	4	high
5.6	0	4	high
5.7	0	1	very low
5.8	1	2	medium
5.9	1	6	very high
6.0	4	5	very high
6.1	0	4	high
6.2	0	0	absent
6.3	0	0	absent
6.4	0	2	medium
6.5	2	3	high
6.6	1	4	high
6.7	1	4	high
6.8	2	3	high
6.9	0	4	high
7.0	2	3	high
7.1	1	4	high
7.2	1	4	high
7.3	2	3	high
7.4	0	6	very high
7.5	4	5	very high
7.6	1	6	very high
7.7	1	3	high
7.8	1	4	high

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
7.9	2	9	very high
8.0	6	9	very high
8.1	1	9	very high
8.2	2	3	high
8.3	0	3	high
8.4	1	4	high
8.5	3	5	very high
8.6	1	4	high
8.7	0	2	medium
8.8	1	2	medium
8.9	1	4	high
9.0	2	3	high
9.1	0	3	high
9.2	1	4	high
9.3	3	5	very high
9.4	1	9	very high
9.5	5	6	very high
9.6	0	6	very high
9.7	1	3	high
9.8	2	3	high
9.9	0	5	very high
10.0	3	7	very high
10.1	4	10	very high
10.2	3	9	very high
10.3	2	6	very high
10.4	1	8	very high
10.5	5	7	very high
10.6	1	6	very high
10.7	0	3	high
10.8	2	3	high
10.9	1	7	very high
11.0	4	6	very high
11.1	1	8	very high
11.2	3	8	very high
11.3	4	11	very high
11.4	4	15	very high
11.5	7	12	very high
11.6	1	9	very high
11.7	1	5	very high
11.8	3	4	high
11.9	0	15	very high

MDT 0.0-48.0. Southern Section			
RP	**White-Tailed Deer Carcasses (n)**	**Deer Value**	**Cluster Category**
12.0	12	17	very high
12.1	5	20	very high
12.2	3	8	very high
12.3	0	5	very high
12.4	2	4	high
12.5	2	6	very high
12.6	2	7	very high
12.7	3	5	very high
12.8	0	3	high
12.9	0	7	very high
13.0	7	9	very high
13.1	2	11	very high
13.2	2	4	high
13.3	0	3	high
13.4	1	2	medium
13.5	1	3	high
13.6	1	2	medium
13.7	0	3	high
13.8	2	2	medium
13.9	0	2	medium
14.0	0	0	absent
14.1	0	1	very low
14.2	1	1	very low
14.3	0	1	very low
14.4	0	0	absent
14.5	0	1	very low
14.6	1	1	very low
14.7	0	1	very low
14.8	0	0	absent
14.9	0	0	absent
15.0	0	0	absent
15.1	0	0	absent
15.2	0	2	medium
15.3	2	2	medium
15.4	0	3	high
15.5	1	1	very low
15.6	0	1	very low
15.7	0	0	absent
15.8	0	2	medium
15.9	2	5	very high
16.0	3	5	very high

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
16.1	0	3	high
16.2	0	1	very low
16.3	1	1	very low
16.4	0	1	very low
16.5	0	0	absent
16.6	0	0	absent
16.7	0	0	absent
16.8	0	0	absent
16.9	0	1	very low
17.0	1	1	very low
17.1	0	1	very low
17.2	0	0	absent
17.3	0	0	absent
17.4	0	0	absent
17.5	0	0	absent
17.6	0	0	absent
17.7	0	3	high
17.8	3	3	high
17.9	0	5	very high
18.0	2	5	very high
18.1	3	5	very high
18.2	0	4	high
18.3	1	1	very low
18.4	0	2	medium
18.5	1	1	very low
18.6	0	2	medium
18.7	1	1	very low
18.8	0	1	very low
18.9	0	3	high
19.0	3	4	high
19.1	1	5	very high
19.2	1	3	high
19.3	1	3	high
19.4	1	4	high
19.5	2	5	very high
19.6	2	6	very high
19.7	2	5	very high
19.8	1	3	high
19.9	0	4	high
20.0	3	4	high
20.1	1	4	high

MDT 0.0-48.0. Southern Section			
RP	**White-Tailed Deer Carcasses (n)**	**Deer Value**	**Cluster Category**
20.2	0	1	very low
20.3	0	2	medium
20.4	2	2	medium
20.5	0	2	medium
20.6	0	0	absent
20.7	0	0	absent
20.8	0	0	absent
20.9	0	1	very low
21.0	1	1	very low
21.1	0	1	very low
21.2	0	0	absent
21.3	0	0	absent
21.4	0	0	absent
21.5	0	0	absent
21.6	0	0	absent
21.7	0	0	absent
21.8	0	1	very low
21.9	1	2	medium
22.0	1	4	high
22.1	2	3	high
22.2	0	4	high
22.3	2	2	medium
22.4	0	4	high
22.5	2	2	medium
22.6	0	2	medium
22.7	0	0	absent
22.8	0	1	very low
22.9	1	4	high
23.0	3	4	high
23.1	0	3	high
23.2	0	1	very low
23.3	1	2	medium
23.4	1	3	high
23.5	1	3	high
23.6	1	2	medium
23.7	0	1	very low
23.8	0	0	absent
23.9	0	2	medium
24.0	2	4	high
24.1	2	4	high
24.2	0	4	high

MDT 0.0-48.0. Southern Section			
RP	**White-Tailed Deer Carcasses (n)**	**Deer Value**	**Cluster Category**
24.3	2	2	medium
24.4	0	2	medium
24.5	0	0	absent
24.6	0	0	absent
24.7	0	0	absent
24.8	0	0	absent
24.9	0	0	absent
25.0	0	0	absent
25.1	0	0	absent
25.2	0	0	absent
25.3	0	0	absent
25.4	0	0	absent
25.5	0	0	absent
25.6	0	0	absent
25.7	0	0	absent
25.8	0	0	absent
25.9	0	1	very low
26.0	1	1	very low
26.1	0	2	medium
26.2	1	1	very low
26.3	0	1	very low
26.4	0	0	absent
26.5	0	0	absent
26.6	0	0	absent
26.7	0	0	absent
26.8	0	1	very low
26.9	1	2	medium
27.0	1	3	high
27.1	1	4	high
27.2	2	4	high
27.3	1	3	high
27.4	0	3	high
27.5	2	2	medium
27.6	0	2	medium
27.7	0	1	very low
27.8	1	2	medium
27.9	1	2	medium
28.0	0	2	medium
28.1	1	1	very low
28.2	0	1	very low
28.3	0	0	absent

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
28.4	0	0	absent
28.5	0	0	absent
28.6	0	0	absent
28.7	0	0	absent
28.8	0	0	absent
28.9	0	0	absent
29.0	0	2	medium
29.1	2	2	medium
29.2	0	2	medium
29.3	0	0	absent
29.4	0	2	medium
29.5	2	3	high
29.6	1	3	high
29.7	0	2	medium
29.8	1	1	very low
29.9	0	3	high
30.0	2	3	high
30.1	1	3	high
30.2	0	1	very low
30.3	0	0	absent
30.4	0	0	absent
30.5	0	0	absent
30.6	0	0	absent
30.7	0	0	absent
30.8	0	0	absent
30.9	0	2	medium
31.0	2	2	medium
31.1	0	2	medium
31.2	0	0	absent
31.3	0	0	absent
31.4	0	1	very low
31.5	1	1	very low
31.6	0	1	very low
31.7	0	0	absent
31.8	0	0	absent
31.9	0	1	very low
32.0	1	1	very low
32.1	0	1	very low
32.2	0	0	absent
32.3	0	0	absent
32.4	0	0	absent

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
32.5	0	0	absent
32.6	0	0	absent
32.7	0	0	absent
32.8	0	0	absent
32.9	0	2	medium
33.0	2	2	medium
33.1	0	2	medium
33.2	0	0	absent
33.3	0	0	absent
33.4	0	0	absent
33.5	0	1	very low
33.6	1	1	very low
33.7	0	1	very low
33.8	0	0	absent
33.9	0	2	medium
34.0	2	2	medium
34.1	0	3	high
34.2	1	1	very low
34.3	0	1	very low
34.4	0	0	absent
34.5	0	0	absent
34.6	0	0	absent
34.7	0	0	absent
34.8	0	0	absent
34.9	0	4	high
35.0	4	5	very high
35.1	1	7	very high
35.2	2	3	high
35.3	0	2	medium
35.4	0	1	very low
35.5	1	1	very low
35.6	0	1	very low
35.7	0	2	medium
35.8	2	3	high
35.9	1	5	very high
36.0	2	3	high
36.1	0	7	very high
36.2	5	6	very high
36.3	1	6	very high
36.4	0	2	medium
36.5	1	2	medium

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
36.6	1	2	medium
36.7	0	2	medium
36.8	1	2	medium
36.9	1	6	very high
37.0	4	5	very high
37.1	0	5	very high
37.2	1	1	very low
37.3	0	3	high
37.4	2	3	high
37.5	1	4	high
37.6	1	2	medium
37.7	0	2	medium
37.8	1	1	very low
37.9	0	8	very high
38.0	7	7	very high
38.1	0	8	very high
38.2	1	1	very low
38.3	0	1	very low
38.4	0	1	very low
38.5	1	2	medium
38.6	1	2	medium
38.7	0	1	very low
38.8	0	0	absent
38.9	0	3	high
39.0	3	3	high
39.1	0	4	high
39.2	1	2	medium
39.3	1	2	medium
39.4	0	1	very low
39.5	0	0	absent
39.6	0	0	absent
39.7	0	0	absent
39.8	0	3	high
39.9	3	10	very high
40.0	7	11	very high
40.1	1	10	very high
40.2	2	5	very high
40.3	2	5	very high
40.4	1	4	high
40.5	1	2	medium
40.6	0	1	very low

MDT 0.0-48.0. Southern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
40.7	0	0	absent
40.8	0	1	very low
40.9	1	1	very low
41.0	0	1	very low
41.1	0	0	absent
41.2	0	0	absent
41.3	0	0	absent
41.4	0	3	high
41.5	3	5	very high
41.6	2	5	very high
41.7	0	3	high
41.8	1	1	very low
41.9	0	8	very high
42.0	7	7	very high
42.1	0	7	very high
42.2	0	2	medium
42.3	2	5	very high
42.4	3	8	very high
42.5	3	7	very high
42.6	1	5	very high
42.7	1	4	high
42.8	2	3	high
42.9	0	8	very high
43.0	6	6	very high
43.1	0	8	very high
43.2	2	2	medium
43.3	0	2	medium
43.4	0	1	very low
43.5	1	1	very low
43.6	0	1	very low
43.7	0	2	medium
43.8	2	3	high
43.9	1	5	very high
44.0	2	4	high
44.1	1	3	high
44.2	0	1	very low
44.3	0	0	absent
44.4	0	3	high
44.5	3	3	high
44.6	0	3	high
44.7	0	0	absent

MDT 0.0-48.0. Southern Section			
RP	**White-Tailed Deer Carcasses (n)**	**Deer Value**	**Cluster Category**
44.8	0	0	absent
44.9	0	2	medium
45.0	2	3	high
45.1	1	4	high
45.2	1	2	medium
45.3	0	1	very low
45.4	0	3	high
45.5	3	4	high
45.6	1	4	high
45.7	0	2	medium
45.8	1	1	very low
45.9	0	6	very high
46.0	5	5	very high
46.1	0	5	very high
46.2	0	1	very low
46.3	1	2	medium
46.4	1	3	high
46.5	1	2	medium
46.6	0	1	very low
46.7	0	0	absent
46.8	0	0	absent
46.9	0	3	high
47.0	3	3	high
47.1	0	3	high
47.2	0	0	absent
47.3	0	0	absent
47.4	0	0	absent
47.5	0	0	absent
47.6	0	0	absent
47.7	0	1	very low
47.8	1	1	very low

Central Section – MDT 48.0-80.0.

MDT 48.0-80.0 Central Section			
RP	**"Deer" Carcasses (n)**	**Deer Value**	**Cluster Category**
48.0	10.0	18	very high
49.0	8.0	23	very high
50.0	5.0	21	very high
51.0	8.0	15	very high
52.0	2.0	12	very high
53.0	2.0	6	high
54.0	2.0	7	high
55.0	3.0	10	very high
56.0	5.0	11	very high
57.0	3.0	10	very high
58.0	2.0	5	medium
59.0	0	4	medium
60.0	2.0	4	medium
61.0	2.0	7	high
62.0	3.0	7	high
63.0	2.0	6	high
64.0	1.0	5	medium
65.0	2.0	5	medium
66.0	2.0	5	medium
67.0	1.0	3	low
68.0	0	2	low
69.0	1.0	1	very low
70.0	0	3	low
71.0	2.0	3	low
72.0	1.0	4	medium
73.0	1.0	2	low
74.0	0	2	low
75.0	1.0	1	very low
76.0	0	1	very low
77.0	0	1	very low
78.0	1.0	7	high
79.0	6.0	7	high

Northern Section – MDT 80.0-91.1.

MDT 80.0-91.1 Northern Section			
RP	White-Tailed Deer Carcasses (n)	Deer Value	Cluster Category
80.0	1	1	very low
80.1	0	1	very low
80.2	0	0	absent
80.3	0	0	absent
80.4	0	0	absent
80.5	0	0	absent
80.6	0	0	absent
80.7	0	0	absent
80.8	0	0	absent
80.9	0	0	absent
81.0	0	0	absent
81.1	0	0	absent
81.2	0	0	absent
81.3	0	0	absent
81.4	0	0	absent
81.5	0	0	absent
81.6	0	0	absent
81.7	0	0	absent
81.8	0	0	absent
81.9	0	0	absent
82.0	0	0	absent
82.1	0	0	absent
82.2	0	0	absent
82.3	0	0	absent
82.4	0	0	absent
82.5	0	0	absent
82.6	0	0	absent
82.7	0	1	very low
82.8	1	1	very low
82.9	0	3	very high
83.0	2	2	medium
83.1	0	2	medium
83.2	0	3	very high
83.3	3	4	very high
83.4	1	6	very high
83.5	2	4	very high
83.6	1	4	very high
83.7	1	2	medium

MDT 80.0-91.1 Northern Section			
RP	**White-Tailed Deer Carcasses (n)**	**Deer Value**	**Cluster Category**
83.8	0	1	very low
83.9	0	0	absent
84.0	0	0	absent
84.1	0	2	medium
84.2	2	2	medium
84.3	0	5	very high
84.4	3	5	very high
84.5	2	5	very high
84.6	0	2	medium
84.7	0	1	very low
84.8	1	2	medium
84.9	1	2	medium
85.0	0	1	very low
85.1	0	1	very low
85.2	1	1	very low
85.3	0	2	medium
85.4	1	2	medium
85.5	1	4	very high
85.6	2	3	very high
85.7	0	3	very high
85.8	1	2	medium
85.9	1	3	very high
86.0	1	2	medium
86.1	0	1	very low
86.2	0	3	very high
86.3	3	3	very high
86.4	0	3	very high
86.5	0	0	absent
86.6	0	0	absent
86.7	0	0	absent
86.8	0	0	absent
86.9	0	1	very low
87.0	1	2	medium
87.1	1	3	very high
87.2	1	2	medium
87.3	0	1	very low
87.4	0	0	absent
87.5	0	0	absent
87.6	0	1	very low

MDT 80.0-91.1 Northern Section			
RP	**White-Tailed Deer Carcasses (n)**	**Deer Value**	**Cluster Category**
87.7	1	1	very low
87.8	0	1	very low
87.9	0	0	absent
88.0	0	0	absent
88.1	0	0	absent
88.2	0	0	absent
88.3	0	0	absent
88.4	0	2	medium
88.5	2	4	very high
88.6	2	4	very high
88.7	0	2	medium
88.8	0	0	absent
88.9	0	2	medium
89.0	2	2	medium
89.1	0	2	medium
89.2	0	0	absent
89.3	0	1	very low
89.4	1	1	very low
89.5	0	1	very low
89.6	0	0	absent
89.7	0	0	absent
89.8	0	0	absent
89.9	0	0	absent
90.0	0	0	absent
90.1	0	0	absent
90.2	0	0	absent
90.3	0	0	absent
90.4	0	2	medium
90.5	2	2	medium
90.6	0	2	medium
90.7	0	1	very low
90.8	1	1	very low
90.9	0	1	very low
91.0	0	1	very low
91.1	1	1	very low

MHP Entire Route 0.0-91.1

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
0.0	0	0	absent
0.1	0	0	absent
0.2	0	0	absent
0.3	0	0	absent
0.4	0	0	absent
0.5	0	0	absent
0.6	0	0	absent
0.7	0	0	absent
0.8	0	0	absent
0.9	0	0	absent
1	0	0	absent
1.1	0	0	absent
1.2	0	0	absent
1.3	0	0	absent
1.4	0	0	absent
1.5	0	0	absent
1.6	0	0	absent
1.7	0	1	very low
1.8	1	1	very low
1.9	0	1	very low
2.0	0	0	absent
2.1	0	0	absent
2.2	0	0	absent
2.3	0	1	very low
2.4	1	1	very low
2.5	0	1	very low
2.6	0	0	absent
2.7	0	0	absent
2.8	0	0	absent
2.9	0	0	absent
3.0	0	2	very high
3.1	2	2	very high
3.2	0	2	very high
3.3	0	0	absent
3.4	0	0	absent
3.5	0	0	absent
3.6	0	0	absent
3.7	0	0	absent
3.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
3.9	0	0	absent
4.0	0	2	very high
4.1	2	3	very high
4.2	1	4	very high
4.3	1	2	very high
4.4	0	1	very low
4.5	0	0	absent
4.6	0	0	absent
4.7	0	1	very low
4.8	1	1	very low
4.9	0	2	very high
5.0	1	1	very low
5.1	0	2	very high
5.2	1	1	very low
5.3	0	1	very low
5.4	0	0	absent
5.5	0	0	absent
5.6	0	0	absent
5.7	0	0	absent
5.8	0	0	absent
5.9	0	0	absent
6.0	0	0	absent
6.1	0	0	absent
6.2	0	0	absent
6.3	0	0	absent
6.4	0	0	absent
6.5	0	0	absent
6.6	0	1	very low
6.7	1	2	very high
6.8	1	2	very high
6.9	0	1	very low
7.0	0	0	absent
7.1	0	0	absent
7.2	0	0	absent
7.3	0	0	absent
7.4	0	0	absent
7.5	0	0	absent
7.6	0	0	absent
7.7	0	0	absent
7.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
7.9	0	0	absent
8.0	0	0	absent
8.1	0	0	absent
8.2	0	0	absent
8.3	0	0	absent
8.4	0	0	absent
8.5	0	0	absent
8.6	0	0	absent
8.7	0	0	absent
8.8	0	0	absent
8.9		1	very low
9.0	1	1	very low
9.1	0	1	very low
9.2	0	0	absent
9.3	0	0	absent
9.4	0	0	absent
9.5	0	0	absent
9.6	0	0	absent
9.7	0	0	absent
9.8	0	0	absent
9.9	0	0	absent
10.0	0	0	absent
10.1	0	2	very high
10.2	2	3	very high
10.3	1	3	very high
10.4	0	1	very low
10.5	0	0	absent
10.6	0	0	absent
10.7	0	1	very low
10.8	1	1	very low
10.9	0	1	very low
11.0	0	1	very low
11.1	1	2	very high
11.2	1	3	very high
11.3	1	3	very high
11.4	1	5	very high
11.5	3	4	very high
11.6	0	4	very high
11.7	1	1	very low
11.8	0	2	very high

MHP 0.0-91.1			
RP	**Collisions With Wild Animals (n)**	**Deer Value**	**Cluster Category**
11.9	1	1	very low
12.0	0	2	very high
12.1	1	1	very low
12.2	0	1	very low
12.3	0	0	absent
12.4	0	2	very high
12.5	2	3	very high
12.6	1	3	very high
12.7	0	1	very low
12.8	0	1	very low
12.9	1	1	very low
13.0	0	2	very high
13.1	1	1	very low
13.2	0	1	very low
13.3	0	0	absent
13.4	0	0	absent
13.5	0	0	absent
13.6	0	2	very high
13.7	2	3	very high
13.8	1	3	very high
13.9	0	1	very low
14.0	0	0	absent
14.1	0	0	absent
14.2	0	0	absent
14.3	0	0	absent
14.4	0	0	absent
14.5	0	0	absent
14.6	0	1	very low
14.7	1	2	very high
14.8	1	2	very high
14.9	0	1	very low
15.0	0	0	absent
15.1	0	1	very low
15.2	1	2	very high
15.3	1	2	very high
15.4	0	2	very high
15.5	1	1	very low
15.6	0	1	very low
15.7	0	0	absent
15.8	0	0	absent

MHP 0.0-91.1			
RP	**Collisions With Wild Animals (n)**	**Deer Value**	**Cluster Category**
15.9	0	2	very high
16.0	2	2	very high
16.1	0	2	very high
16.2	0	0	absent
16.3	0	1	very low
16.4	1	2	very high
16.5	1	2	very high
16.6	0	2	very high
16.7	1	2	very high
16.8	1	5	very high
16.9	3	6	very high
17.0	2	6	very high
17.1	1	5	very high
17.2	2	3	very high
17.3	0	2	very high
17.4	0	0	absent
17.5	0	0	absent
17.6	0	0	absent
17.7	0	0	absent
17.8	0	1	very low
17.9	1	1	very low
18.0	0	3	very high
18.1	2	2	very high
18.2	0	2	very high
18.3	0	0	absent
18.4	0	0	absent
18.5	0	0	absent
18.6	0	1	very low
18.7	1	1	very low
18.8	0	1	very low
18.9	0	0	absent
19.0	0	0	absent
19.1	0	0	absent
19.2	0	0	absent
19.3	0	0	absent
19.4	0	0	absent
19.5	0	1	very low
19.6	1	1	very low
19.7	0	2	very high
19.8	1	1	very low

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
19.9	0	1	very low
20.0	0	1	very low
20.1	1	1	very low
20.2	0	1	very low
20.3	0	0	absent
20.4	0	0	absent
20.5	0	0	absent
20.6	0	0	absent
20.7	0	0	absent
20.8	0	1	very low
20.9	1	1	very low
21.0	0	2	very high
21.1	1	1	very low
21.2	0	2	very high
21.3	1	1	very low
21.4	0	3	very high
21.5	2	2	very high
21.6	0	2	very high
21.7	0	0	absent
21.8	0	0	absent
21.9	0	1	very low
22.0	1	1	very low
22.1	0	1	very low
22.2	0	1	very low
22.3	1	1	very low
22.4	0	2	very high
22.5	1	1	very low
22.6	0	1	very low
22.7	0	1	very low
22.8	1	1	very low
22.9	0	1	very low
23.0	0	1	very low
23.1	1	2	very high
23.2	1	2	very high
23.3	0	1	very low
23.4	0	0	absent
23.5	0	0	absent
23.6	0	0	absent
23.7	0	0	absent
23.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
23.9	0	0	absent
24.0	0	0	absent
24.1	0	0	absent
24.2	0	0	absent
24.3	0	0	absent
24.4	0	0	absent
24.5	0	0	absent
24.6	0	0	absent
24.7	0	0	absent
24.8	0	0	absent
24.9	0	0	absent
25.0	0	1	very low
25.1	1	1	very low
25.2	0	1	very low
25.3	0	0	absent
25.4	0	0	absent
25.5	0	0	absent
25.6	0	0	absent
25.7	0	1	very low
25.8	1	1	very low
25.9	0	1	very low
26.0	0	1	very low
26.1	1	1	very low
26.2	0	1	very low
26.3	0	0	absent
26.4	0	1	very low
26.5	1	1	very low
26.6	0	1	very low
26.7	0	0	absent
26.8	0	0	absent
26.9	0	1	very low
27.0	1	1	very low
27.1	0	1	very low
27.2	0	0	absent
27.3	0	1	very low
27.4	1	1	very low
27.5	0	1	very low
27.6	0	0	absent
27.7	0	2	very high
27.8	2	3	very high

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
27.9	1	3	very high
28.0	0	2	very high
28.1	1	2	very high
28.2	1	3	very high
28.3	1	3	very high
28.4	1	2	very high
28.5	0	2	very high
28.6	1	2	very high
28.7	1	2	very high
28.8	0	2	very high
28.9	1	1	very low
29.0	0	1	very low
29.1	0	0	absent
29.2	0	0	absent
29.3	0	0	absent
29.4	0	0	absent
29.5	0	0	absent
29.6	0	0	absent
29.7	0	0	absent
29.8	0	0	absent
29.9	0	0	absent
30.0	0	0	absent
30.1	0	0	absent
30.2	0	0	absent
30.3	0	0	absent
30.4	0	0	absent
30.5	0	0	absent
30.6	0	0	absent
30.7	0	0	absent
30.8	0	0	absent
30.9	0	1	very low
31.0	1	2	very high
31.1	1	2	very high
31.2	0	1	very low
31.3	0	0	absent
31.4	0	0	absent
31.5	0	0	absent
31.6	0	0	absent
31.7	0	1	very low
31.8	1	1	very low

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
31.9	0	1	very low
32.0	0	0	absent
32.1	0	0	absent
32.2	0	0	absent
32.3	0	0	absent
32.4	0	0	absent
32.5	0	0	absent
32.6	0	0	absent
32.7	0	0	absent
32.8	0	0	absent
32.9	0	1	very low
33.0	1	2	very high
33.1	1	2	very high
33.2	0	1	very low
33.3	0	1	very low
33.4	1	1	very low
33.5	0	1	very low
33.6	0	0	absent
33.7	0	0	absent
33.8	0	0	absent
33.9	0	0	absent
34.0	0	0	absent
34.1	0	0	absent
34.2	0	0	absent
34.3	0	1.	very low
34.4	1	1	very low
34.5	0	2	very high
34.6	1	1	very low
34.7	0	1	very low
34.8	0	1	very low
34.9	1	2	very high
35.0	1	2	very high
35.1	0	2	very high
35.2	1	1	very low
35.3	0	1	very low
35.4	0	0	absent
35.5	0	0	absent
35.6	0	0	absent
35.7	0	1	very low
35.8	1	1	very low

MHP 0.0-91.1			
RP	**Collisions With Wild Animals (n)**	**Deer Value**	**Cluster Category**
35.9	0	3	very high
36.0	2	2	very high
36.1	0	3	very high
36.2	1	1	very low
36.3	0	1	very low
36.4	0	1	very low
36.5	1	1	very low
36.6	0	1	very low
36.7	0	0	absent
36.8	0	0	absent
36.9	0	1	very low
37.0	1	1	very low
37.1	0	1	very low
37.2	0	0	absent
37.3	0	0	absent
37.4	0	1	very low
37.5	1	1	very low
37.6	0	1	very low
37.7	0	0	absent
37.8	0	0	absent
37.9	0	0	absent
38.0	0	1	very low
38.1	1	2	very high
38.2	1	2	very high
38.3	0	1	very low
38.4	0	2	very high
38.5	2	2	very high
38.6	0	2	very high
38.7	0	0	absent
38.8	0	1	very low
38.9	1	2	very high
39.0	1	2	very high
39.1	0	1	very low
39.2	0	0	absent
39.3	0	0	absent
39.4	0	0	absent
39.5	0	0	absent
39.6	0	0	absent
39.7	0	0	absent
39.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
39.9	0	0	absent
40.0	0	0	absent
40.1	0	0	absent
40.2	0	0	absent
40.3	0	0	absent
40.4	0	2	very high
40.5	2	2	very high
40.6	0	2	very high
40.7	0	0	absent
40.8	0	0	absent
40.9	0	1	very low
41.0	1	2	very high
41.1	1	2	very high
41.2	0	1	very low
41.3	0	0	absent
41.4	0	1	very low
41.5	1	1	very low
41.6	0	1	very low
41.7	0	0	absent
41.8	0	0	absent
41.9	0	2	very high
42.0	2	2	very high
42.1	0	2	very high
42.2	0	0	absent
42.3	0	1	very low
42.4	1	2	very high
42.5	1	2	very high
42.6	0	1	very low
42.7	0	0	absent
42.8	0	1	very low
42.9	1	1	very low
43.0	0	1	very low
43.1	0	0	absent
43.2	0	0	absent
43.3	0	0	absent
43.4	0	0	absent
43.5	0	0	absent
43.6	0	0	absent
43.7	0	0	absent
43.8	0	2	very high

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
43.9	2	6	very high
44.0	4	6	very high
44.1	0	4	very high
44.2	0	1	very low
44.3	1	1	very low
44.4	0	1	very low
44.5	0	0	absent
44.6	0	0	absent
44.7	0	0	absent
44.8	0	0	absent
44.9	0	0	absent
45.0	0	1	very low
45.1	1	1	very low
45.2	0	1	very low
45.3	0	1	very low
45.4	1	1	very low
45.5	0	1	very low
45.6	0	1	very low
45.7	1	2	very high
45.8	1	2	very high
45.9	0	1	very low
46.0	0	0	absent
46.1	0	0	absent
46.2	0	0	absent
46.3	0	0	absent
46.4	0	0	absent
46.5	0	0	absent
46.6	0	0	absent
46.7	0	0	absent
46.8	0	0	absent
46.9	0	0	absent
47.0	0	1	very low
47.1	1	1	very low
47.2	0	2	very high
47.3	1	2	very high
47.4	1	2	very high
47.5	0	1	very low
47.6	0	0	absent
47.7	0	0	absent
47.8	0	1	very low

MHP 0.0-91.1			
RP	**Collisions With Wild Animals (n)**	**Deer Value**	**Cluster Category**
47.9	1	2	very high
48.0	1	2	very high
48.1	0	1	very low
48.2	0	0	absent
48.3	0	0	absent
48.4	0	0	absent
48.5	0	0	absent
48.6	0	0	absent
48.7	0	0	absent
48.8	0	1	very low
48.9	1	1	very low
49.0	0	1	very low
49.1	0	0	absent
49.2	0	1	very low
49.3	1	1	very low
49.4	0	2	very high
49.5	1	2	very high
49.6	1	2	very high
49.7	0	1	very low
49.8	0	2	very high
49.9	2	2	very high
50.0	0	2	very high
50.1	0	0	absent
50.2	0	0	absent
50.3	0	0	absent
50.4	0	2	very high
50.5	2	2	very high
50.6	0	2	very high
50.7	0	1	very low
50.8	1	1	very low
50.9	0	1	very low
51.0	0	1	very low
51.1	1	2	very high
51.2	1	2	very high
51.3	0	2	very high
51.4	1	2	very high
51.5	1	2	very high
51.6	0	1	very low
51.7	0	0	absent
51.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
51.9	0	0	absent
52.0	0	0	absent
52.1	0	0	absent
52.2	0	0	absent
52.3	0	0	absent
52.4	0	1	very low
52.5	1	1	very low
52.6	0	1	very low
52.7	0	0	absent
52.8	0	1	very low
52.9	1	1	very low
53.0	0	1	very low
53.1	0	1	very low
53.2	1	1	very low
53.3	0	1	very low
53.4	0	0	absent
53.5	0	0	absent
53.6	0	0	absent
53.7	0	1	very low
53.8	1	1	very low
53.9	0	4	very high
54.0	3	3	very high
54.1	0	3	very high
54.2	0	0	absent
54.3	0	0	absent
54.4	0	1	very low
54.5	1	1	very low
54.6	0	2	very high
54.7	1	2	very high
54.8	1	2	very high
54.9	0	1	very low
55.0	0	0	absent
55.1	0	0	absent
55.2	0	0	absent
55.3	0	0	absent
55.4	0	1	very low
55.5	1	1	very low
55.6	0	1	very low
55.7	0	2	very high
55.8	2	2	very high

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
55.9	0	2	very high
56.0	0	0	absent
56.1	0	0	absent
56.2	0	0	absent
56.3	0	0	absent
56.4	0	1	very low
56.5	1	2	very high
56.6	1	3	very high
56.7	1	2	very high
56.8	0	2	very high
56.9	1	1	very low
57.0	0	1	very low
57.1	0	0	absent
57.2	0	1	very low
57.3	1	1	very low
57.4	0	1	very low
57.5	0	0	absent
57.6	0	0	absent
57.7	0	0	absent
57.8	0	1	very low
57.9	1	1	very low
58.0	0	1	very low
58.1	0	1	very low
58.2	1	1	very low
58.3	0	2	very high
58.4	1	1	very low
58.5	0	2	very high
58.6	1	1	very low
58.7	0	1	very low
58.8	0	1	very low
58.9	1	1	very low
59.0	0	1	very low
59.1	0	0	absent
59.2	0	0	absent
59.3	0	0	absent
59.4	0	0	absent
59.5	0	1	very low
59.6	1	1	very low
59.7	0	2	very high
59.8	1	1	very low

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
59.9	0	2	very high
60.0	1	1	very low
60.1	0	1	very low
60.2	0	0	absent
60.3	0	0	absent
60.4	0	2	very high
60.5	2	2	very high
60.6	0	5	very high
60.7	3	4	very high
60.8	1	4	very high
60.9	0	1	very low
61.0	0	0	absent
61.1	0	1	very low
61.2	1	1	very low
61.3	0	1	very low
61.4	0	0	absent
61.5	0	0	absent
61.6	0	0	absent
61.7	0	0	absent
61.8	0	0	absent
61.9	0	0	absent
62.0	0	0	absent
62.1	0	0	absent
62.2	0	0	absent
62.3	0	0	absent
62.4	0	0	absent
62.5	0	0	absent
62.6	0	0	absent
62.7	0	0	absent
62.8	0	1	very low
62.9	1	1	very low
63.0	0	1	very low
63.1	0	0	absent
63.2	0	0	absent
63.3	0	0	absent
63.4	0	0	absent
63.5	0	0	absent
63.6	0	0	absent
63.7	0	0	absent
63.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
63.9	0	0	absent
64.0	0	0	absent
64.1	0	0	absent
64.2	0	0	absent
64.3	0	0	absent
64.4	0	0	absent
64.5	0	0	absent
64.6	0	0	absent
64.7	0	0	absent
64.8	0	0	absent
64.9	0	0	absent
65.0	0	0	absent
65.1	0	0	absent
65.2	0	0	absent
65.3	0	0	absent
65.4	0	0	absent
65.5	0	0	absent
65.6	0	0	absent
65.7	0	1	very low
65.8	1	1	very low
65.9	0	1	very low
66.0	0	0	absent
66.1	0	0	absent
66.2	0	0	absent
66.3	0	1	very low
66.4	1	1	very low
66.5	0	1	very low
66.6	0	0	absent
66.7	0	0	absent
66.8	0	0	absent
66.9	0	0	absent
67.0	0	0	absent
67.1	0	0	absent
67.2	0	1	very low
67.3	1	1	very low
67.4	0	1	very low
67.5	0	0	absent
67.6	0	0	absent
67.7	0	0	absent
67.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
67.9	0	0	absent
68.0	0	0	absent
68.1	0	0	absent
68.2	0	0	absent
68.3	0	0	absent
68.4	0	0	absent
68.5	0	0	absent
68.6	0	0	absent
68.7	0	0	absent
68.8	0	0	absent
68.9	0	0	absent
69.0	0	0	absent
69.1	0	0	absent
69.2	0	0	absent
69.3	0	0	absent
69.4	0	0	absent
69.5	0	0	absent
69.6	0	0	absent
69.7	0	0	absent
69.8	0	1	very low
69.9	1	1	very low
70.0	0	1	very low
70.1	0	0	absent
70.2	0	1	very low
70.3	1	1	very low
70.4	0	1	very low
70.5	0	0	absent
70.6	0	0	absent
70.7	0	0	absent
70.8	0	0	absent
70.9	0	0	absent
71.0	0	0	absent
71.1	0	0	absent
71.2	0	0	absent
71.3	0	0	absent
71.4	0	0	absent
71.5	0	0	absent
71.6	0	0	absent
71.7	0	0	absent
71.8	0	0	absent

MHP 0.0-91.1			
RP	**Collisions With Wild Animals (n)**	**Deer Value**	**Cluster Category**
71.9	0	0	absent
72.0	0	0	absent
72.1	0	0	absent
72.2	0	0	absent
72.3	0	0	absent
72.4	0	0	absent
72.5	0	0	absent
72.6	0	0	absent
72.7	0	0	absent
72.8	0	0	absent
72.9	0	0	absent
73.0	0	0	absent
73.1	0	0	absent
73.2	0	0	absent
73.3	0	0	absent
73.4	0	0	absent
73.5	0	0	absent
73.6	0	0	absent
73.7	0	0	absent
73.8	0	0	absent
73.9	0	0	absent
74.0	0	0	absent
74.1	0	0	absent
74.2	0	0	absent
74.3	0	0	absent
74.4	0	0	absent
74.5	0	0	absent
74.6	0	1	very low
74.7	1	1	very low
74.8	0	1	very low
74.9	0	1	very low
75.0	1	1	very low
75.1	0	1	very low
75.2	0	0	absent
75.3	0	0	absent
75.4	0	0	absent
75.5	0	0	absent
75.6	0	0	absent
75.7	0	0	absent
75.8	0	0	absent

MHP 0.0-91.1			
RP	**Collisions With Wild Animals (n)**	**Deer Value**	**Cluster Category**
75.9	0	0	absent
76.0	0	0	absent
76.1	0	0	absent
76.2	0	0	absent
76.3	0	0	absent
76.4	0	0	absent
76.5	0	0	absent
76.6	0	0	absent
76.7	0	0	absent
76.8	0	0	absent
76.9	0	0	absent
77.0	0	0	absent
77.1	0	0	absent
77.2	0	0	absent
77.3	0	0	absent
77.4	0	2	very high
77.5	2	2	very high
77.6	0	2	very high
77.7	0	0	absent
77.8	0	0	absent
77.9	0	0	absent
78.0	0	0	absent
78.1	0	0	absent
78.2	0	0	absent
78.3	0	0	absent
78.4	0	0	absent
78.5	0	0	absent
78.6	0	0	absent
78.7	0	0	absent
78.8	0	0	absent
78.9	0	0	absent
79.0	0	0	absent
79.1	0	0	absent
79.2	0	0	absent
79.3	0	0	absent
79.4	0	1	very low
79.5	1	1	very low
79.6	0	1	very low
79.7	0	0	absent
79.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
79.9	0	2	very high
80.0	2	2	very high
80.1	0	2	very high
80.2	0	0	absent
80.3	0	0	absent
80.4	0	0	absent
80.5	0	0	absent
80.6	0	0	absent
80.7	0	1	very low
80.8	1	1	very low
80.9	0	1	very low
81.0	0	0	absent
81.1	0	0	absent
81.2	0	0	absent
81.3	0	1	very low
81.4	1	2	very high
81.5	1	2	very high
81.6	0	1	very low
81.7	0	0	absent
81.8	0	2	very high
81.9	2	3	very high
82.0	1	3	very high
82.1	0	2	very high
82.2	1	2	very high
82.3	1	2	very high
82.4	0	2	very high
82.5	1	2	very high
82.6	1	2	very high
82.7	0	1	very low
82.8	0	0	absent
82.9	0	0	absent
83.0	0	1	very low
83.1	1	1	very low
83.2	0	2	very high
83.3	1	1	very low
83.4	0	2	very high
83.5	1	1	very low
83.6	0	1	very low
83.7	0	0	absent
83.8	0	0	absent

MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
83.9	0	0	absent
84.0	0	0	absent
84.1	0	0	absent
84.2	0	1	very low
84.3	1	1	very low
84.4	0	2	very high
84.5	1	1	very low
84.6	0	4	very high
84.7	3	3	very high
84.8	0	4	very high
84.9	1	1	very low
85.0	0	1	very low
85.1	0	1	very low
85.2	1	1	very low
85.3	0	1	very low
85.4	0	1	very low
85.5	1	1	very low
85.6	0	1	very low
85.7	0	0	absent
85.8	0	0	absent
85.9	0	0	absent
86.0	0	0	absent
86.1	0	1	very low
86.2	1	1	very low
86.3	0	1	very low
86.4	0	1	very low
86.5	1	2	very high
86.6	1	2	very high
86.7	0	1	very low
86.8	0	0	absent
86.9	0	0	absent
87.0	0	0	absent
87.1	0	0	absent
87.2	0	0	absent
87.3	0	1	very low
87.4	1	1	very low
87.5	0	1	very low
87.6	0	1	very low
87.7	1	1	very low
87.8	0	2	very high

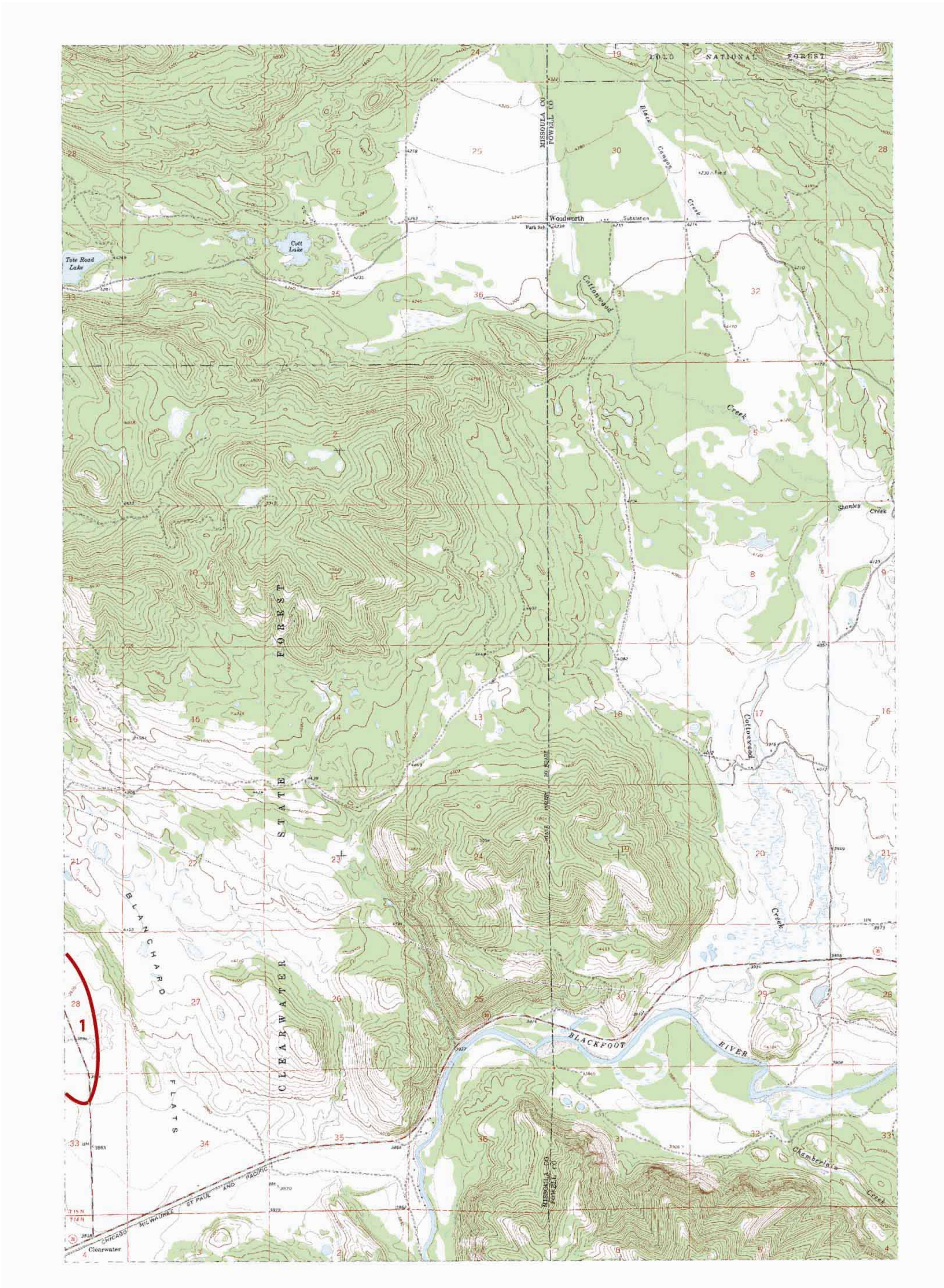
MHP 0.0-91.1			
RP	Collisions With Wild Animals (n)	Deer Value	Cluster Category
87.9	1	2	very high
88.0	1	2	very high
88.1	0	1	very low
88.2	0	0	absent
88.3	0	0	absent
88.4	0	0	absent
88.5	0	1	very low
88.6	1	1	very low
88.7	0	1	very low
88.8	0	0	absent
88.9	0	0	absent
89.0	0	1	very low
89.1	1	1	very low
89.2	0	2	very high
89.3	1	1	very low
89.4	0	1	very low
89.5	0	0	absent
89.6	0	0	absent
89.7	0	0	absent
89.8	0	3	very high
89.9	3	3	very high
90.0	0	4	very high
90.1	1	1	very low
90.2	0	1	very low
90.3	0	0	absent
90.4	0	0	absent
90.5	0	0	absent
90.6	0	0	absent
90.7	0	0	absent
90.8	0	0	absent
90.9	0	0	absent
91.0	0	0	absent
91.1	0	0	absent

APPENDIX D: TOPOGRAPHIC MAPS WITH EXPERT-BASED ANIMAL-VEHICLE COLLISION AND HABITAT LINKAGE ZONES

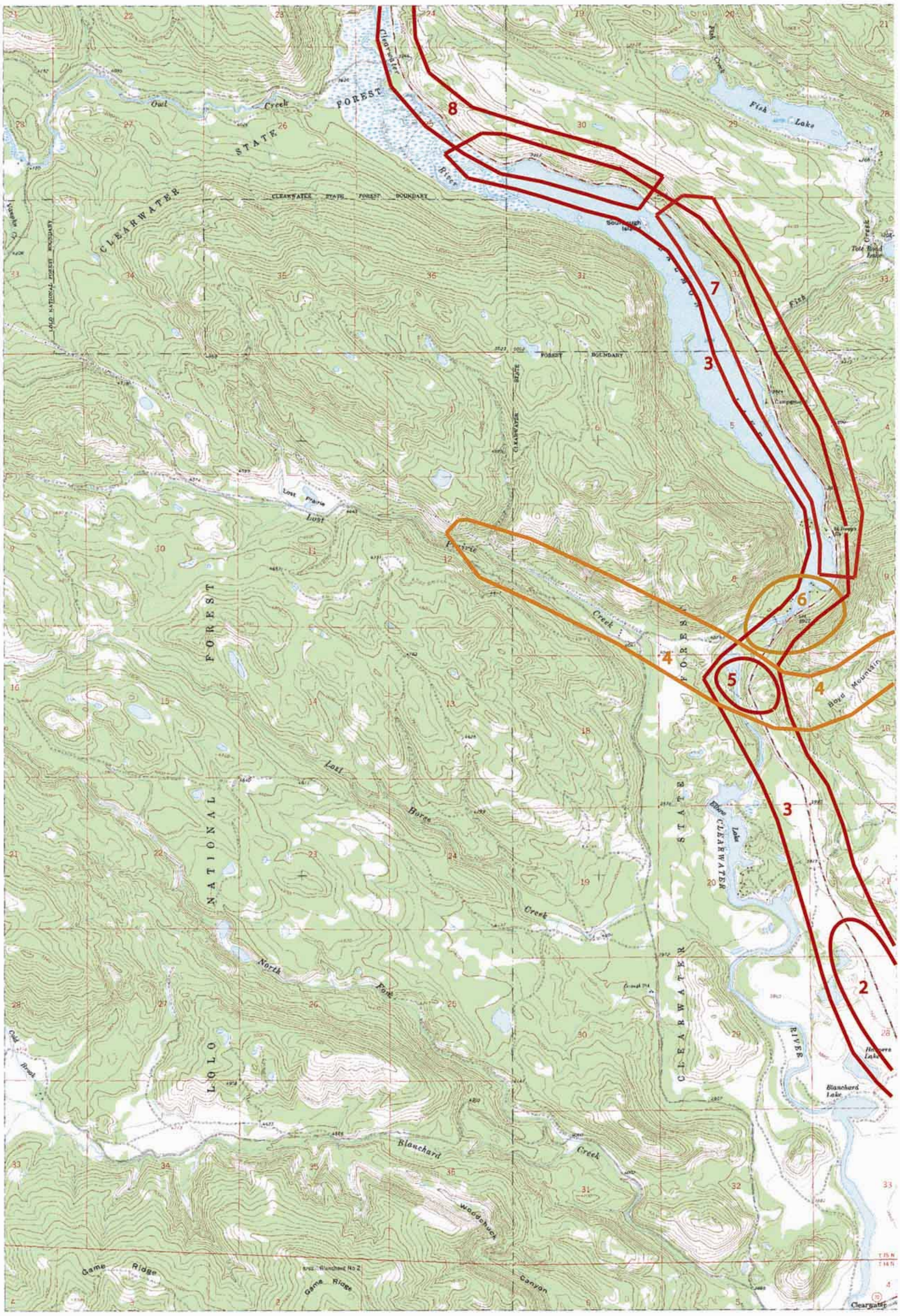
The 1:24,000 topographic maps with colored ovals that mark high frequency animal-vehicle collision and animal crossing areas are also available in digital format (JPEG). Note: The numbers of the colored ovals on the maps correspond to the descriptions in Appendix E.

Map #	Map name
1	Woodworth
2	Salmon Lake
3	Seeley Lake E
4	Seeley Lake W
5	Lake Inez
6	Lake Marshall
7	Holland Lake
8	Cygnet Lake
9	Condon
10	Peck Lake
11	Salmon Prairie
12	Swan peak
13	Cilly Creek
14	Swan Lake
15	Yew Creek
16	Crater Lake
17	Big Fork

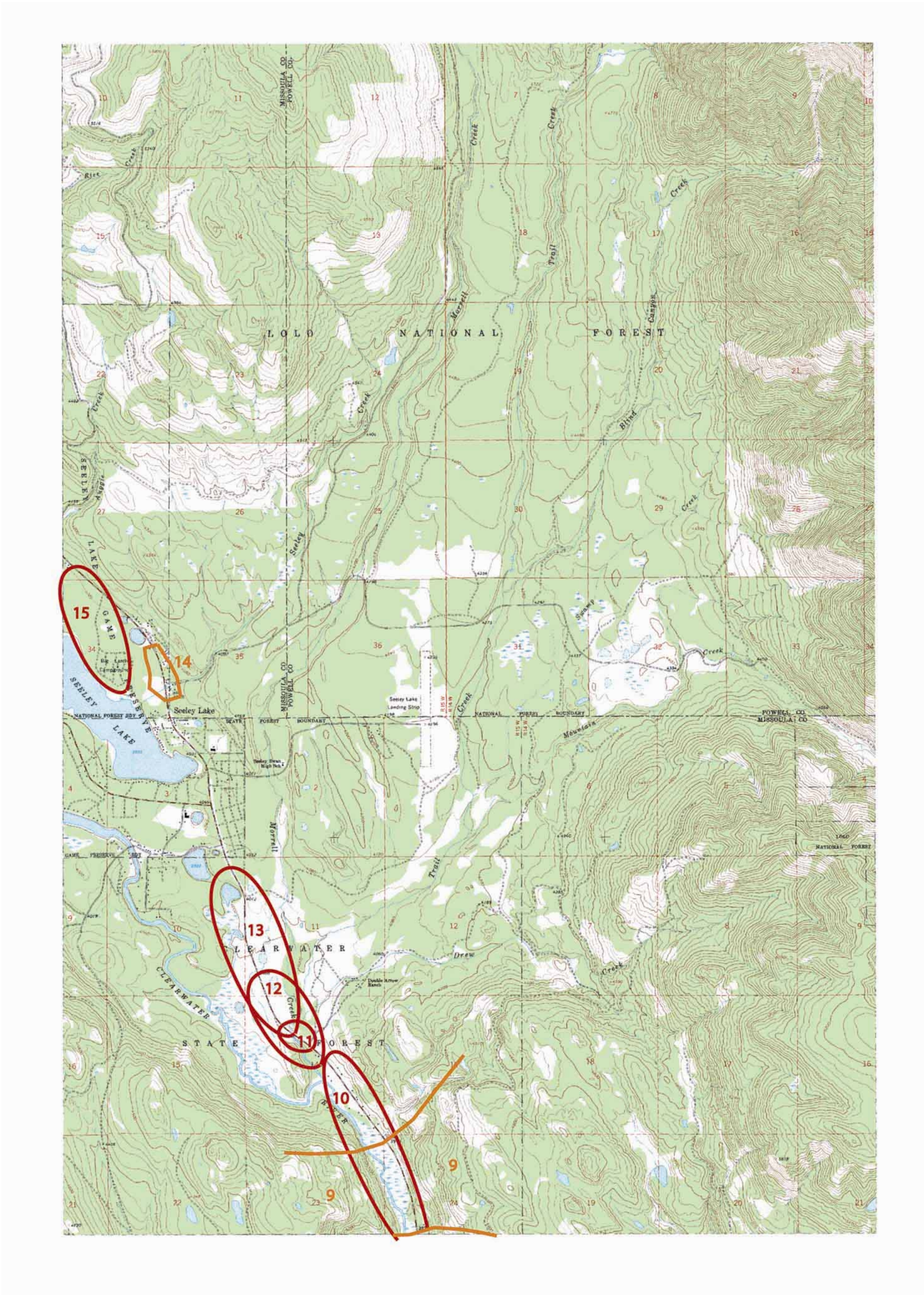
1 Woodworth


LOLO NATIONAL FOREST
MISSOULA CO
POWELL CO
Woodworth
Tote Road Lake
Cott Lake
Black Canyon Creek
Cottonwood Creek
Shanley Creek
CLEARWATER STATE FOREST
BLANCHARD FLATS
BLACKFOOT RIVER
Chamberlain Creek
CHICAGO MILWAUKEE ST PAUL AND PACIFIC
Clearwater
1

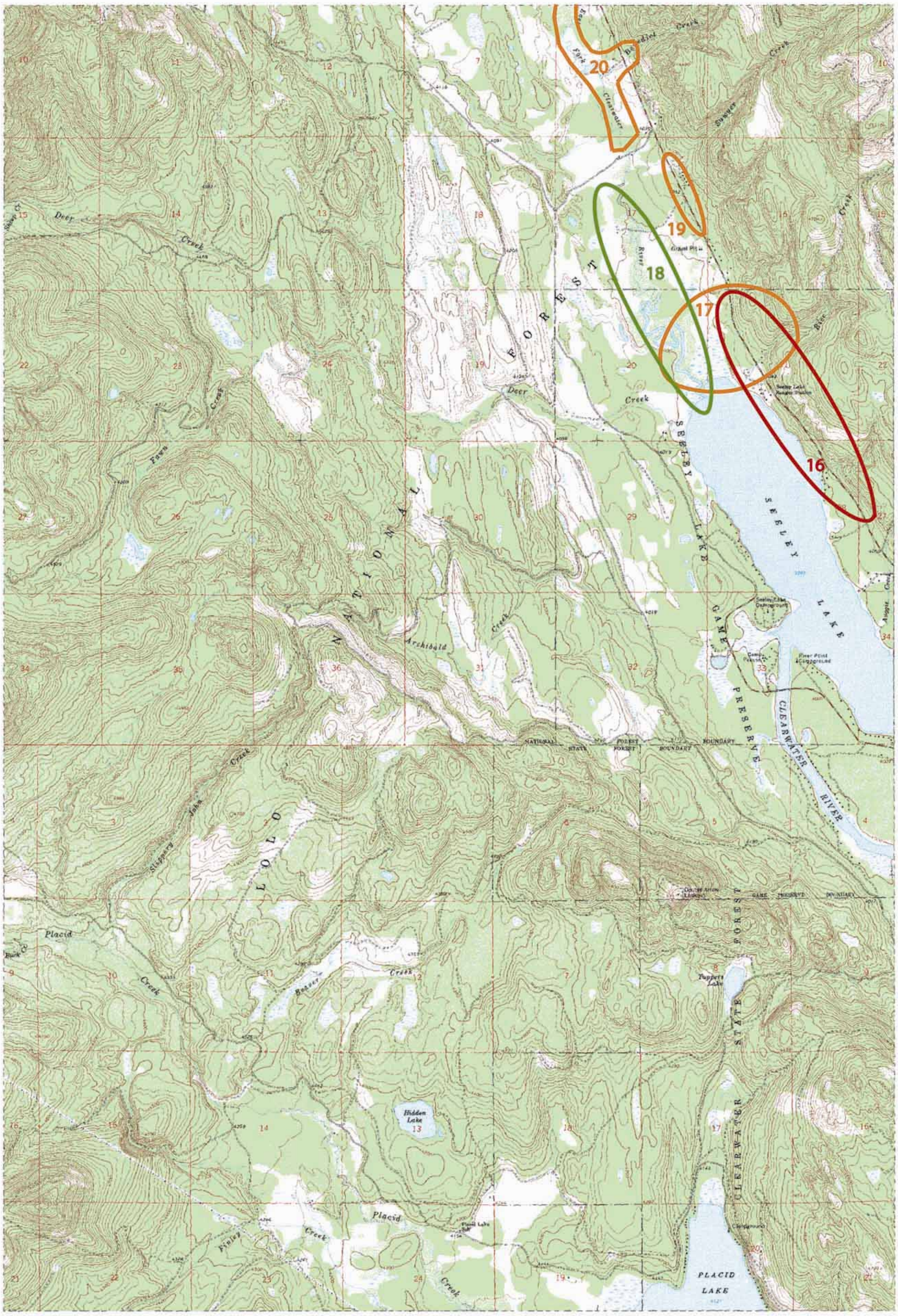
2. Salmon Lake



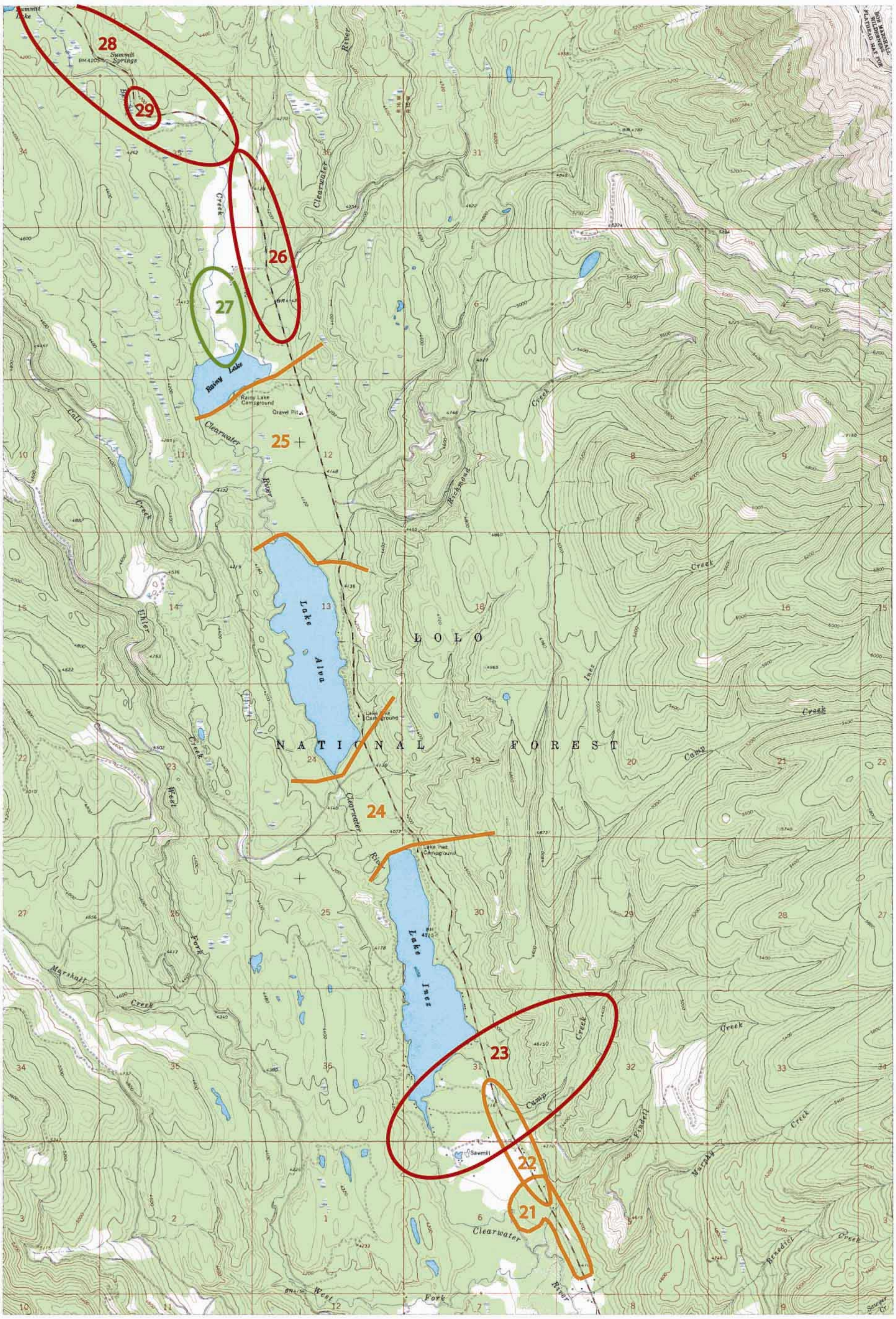
3. Seeley Lake E



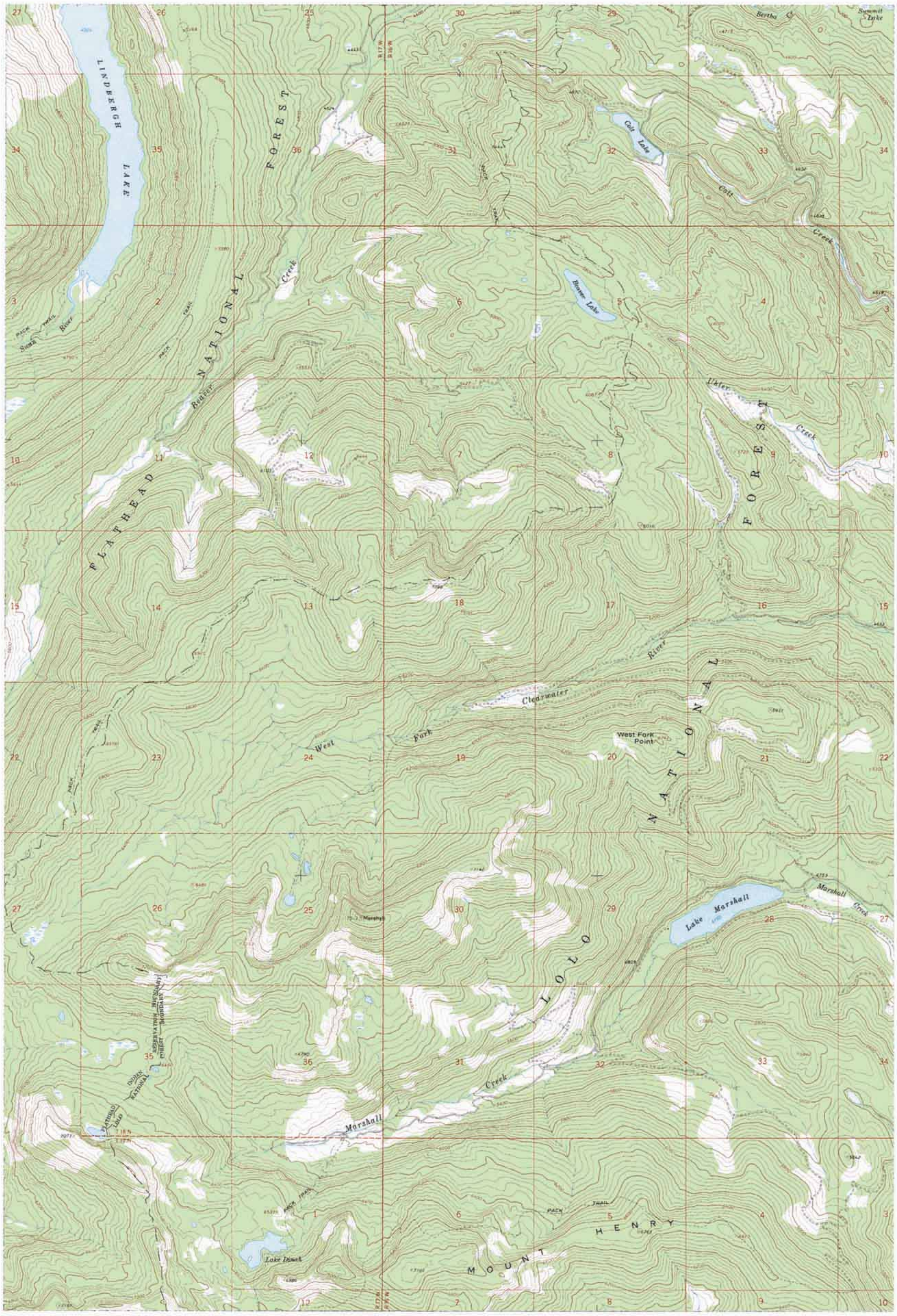
4. Seeley Lake W



5. Lake Inez

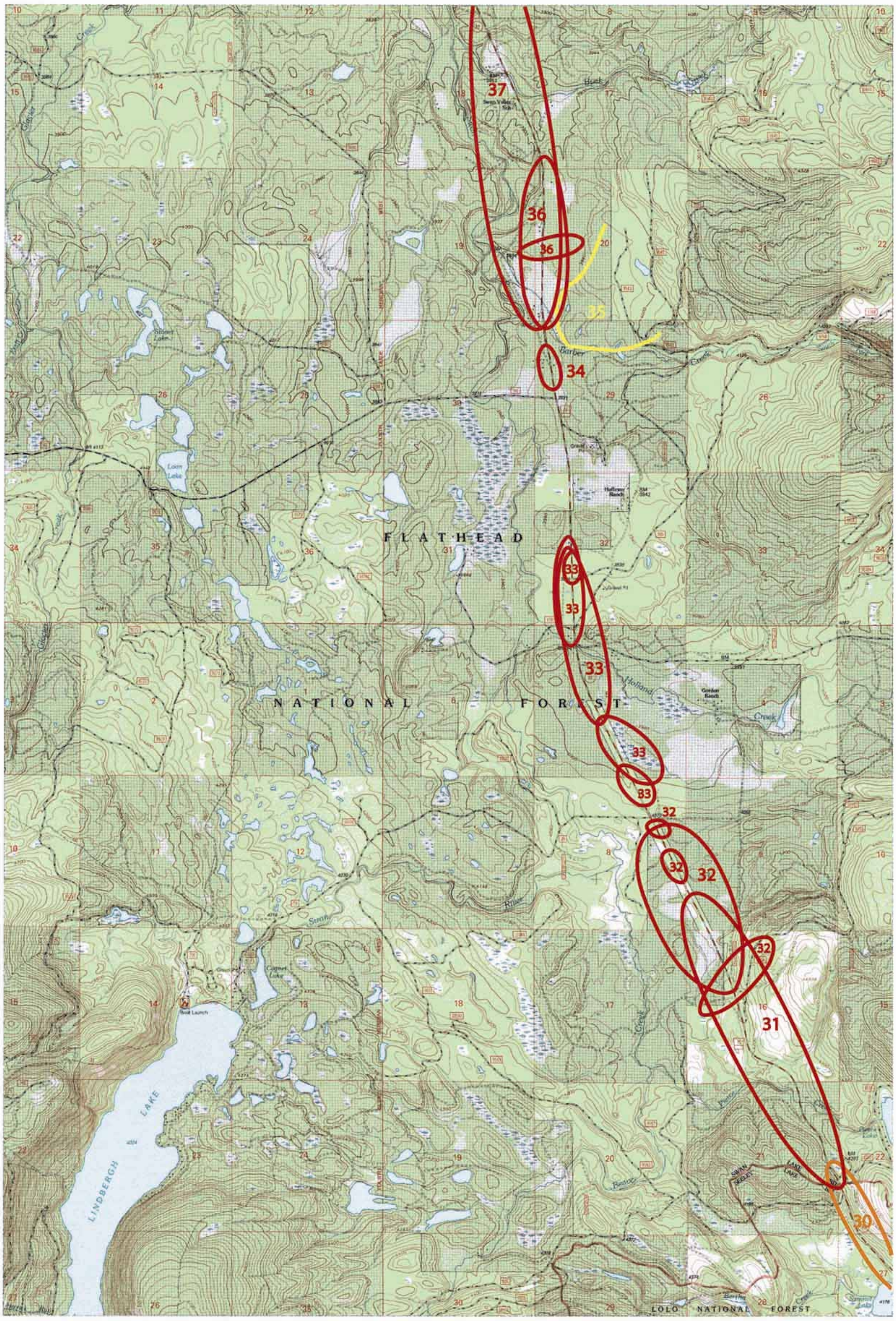

28
29
26
27
25
24
23
22
21
Rainy Lake
Lake Alva
Lake Inez
LOLO
NATIONAL FOREST
Clearwater River
Camp Creek
Sawmill

6. Lake Marshall

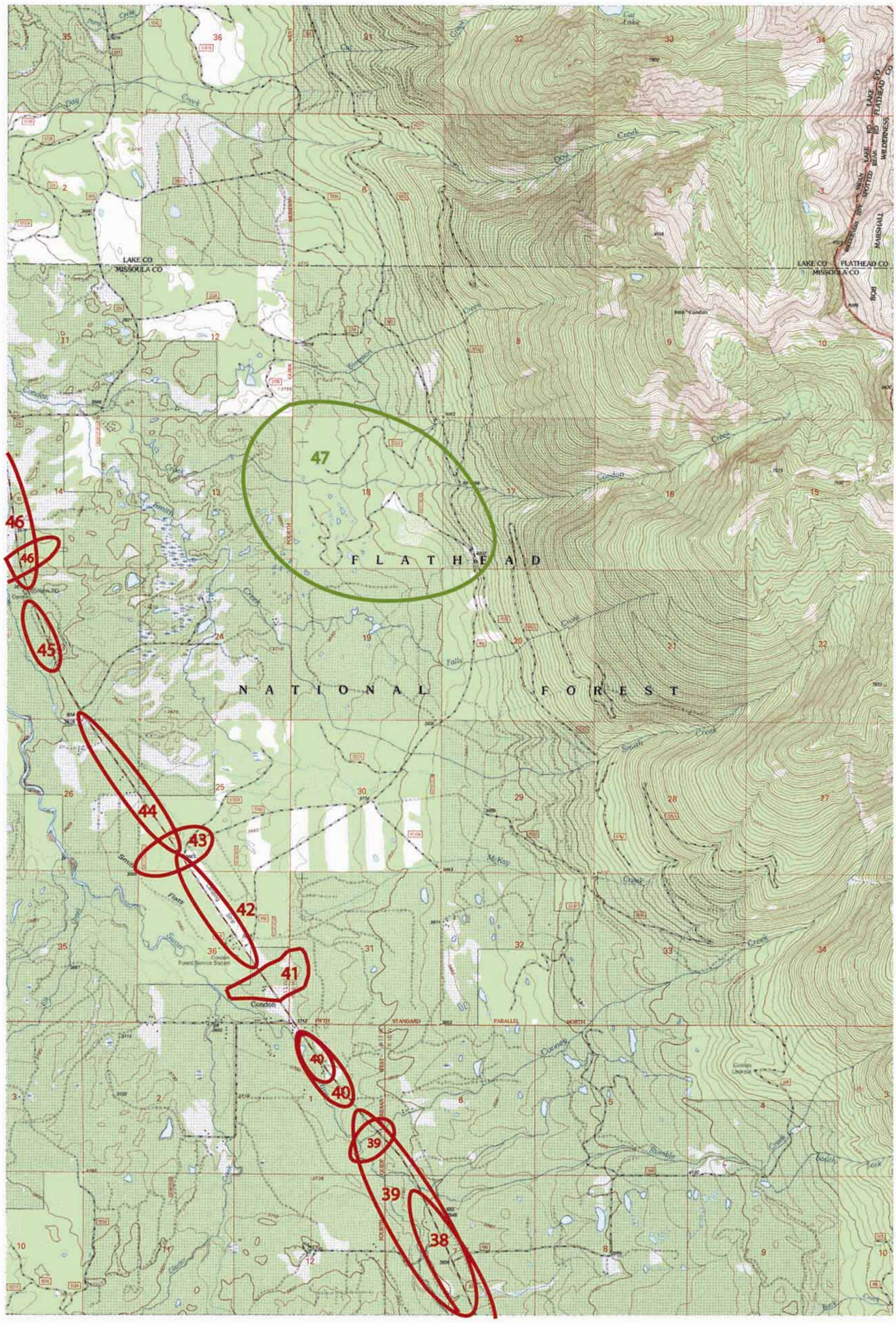


7. Holland Lake

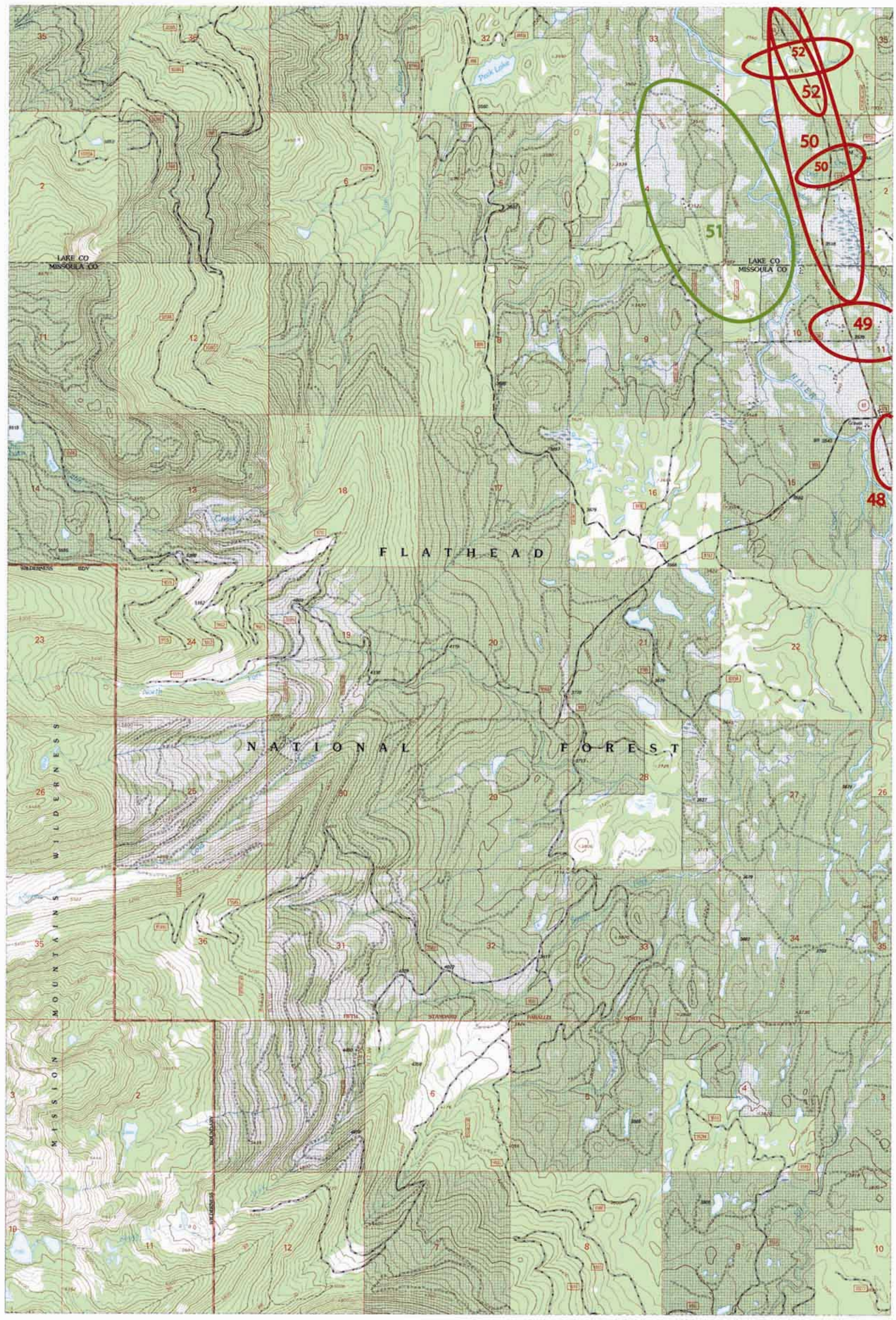
8. Cygnet Lake



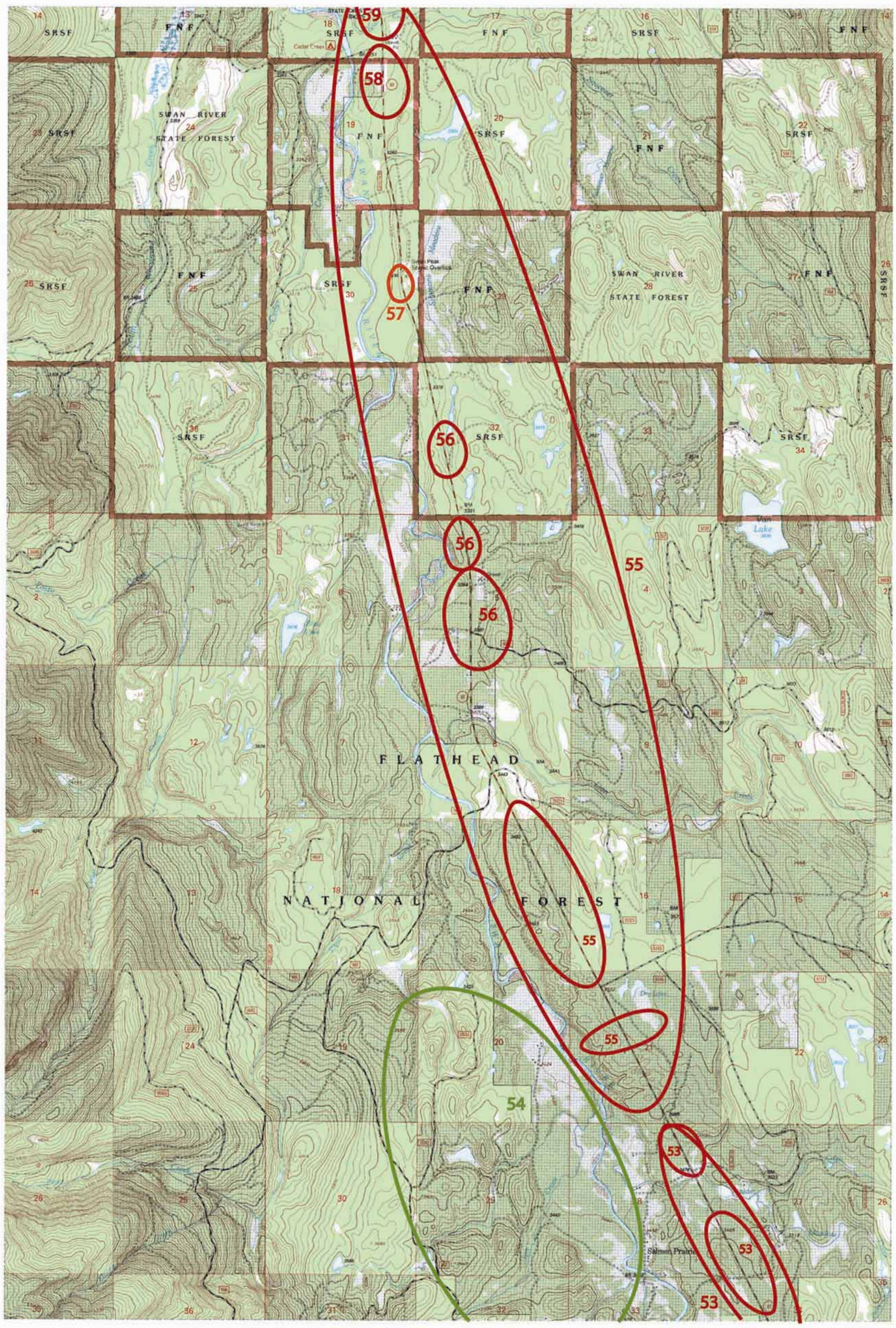
9. Condon


F L A T H E A D
N A T I O N A L
F O R E S T
LAKE CO
MISSOULA CO
LAKE CO FLATHEAD CO
MISSOULA CO
Condon
47
46
46
45
44
43
42
41
40
40
39
39
38

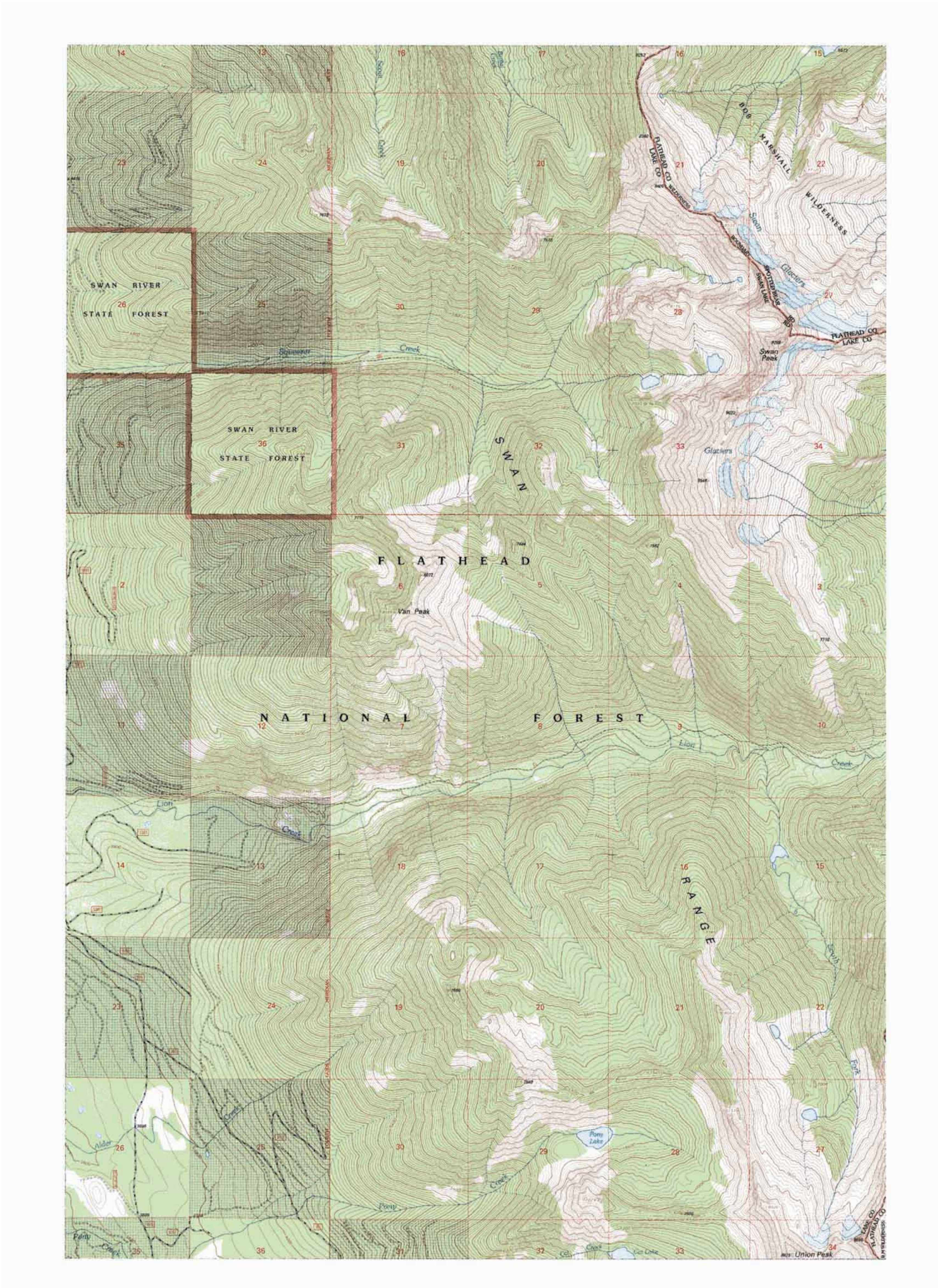
10. Peck Lake


52
52
50
50
51
49
48
LAKE CO
MISSOULA CO
LAKE CO
MISSOULA CO
F L A T H E A D
N A T I O N A L
F O R E S T
M I S S I O N M O U N T A I N S W I L D E R N E S S

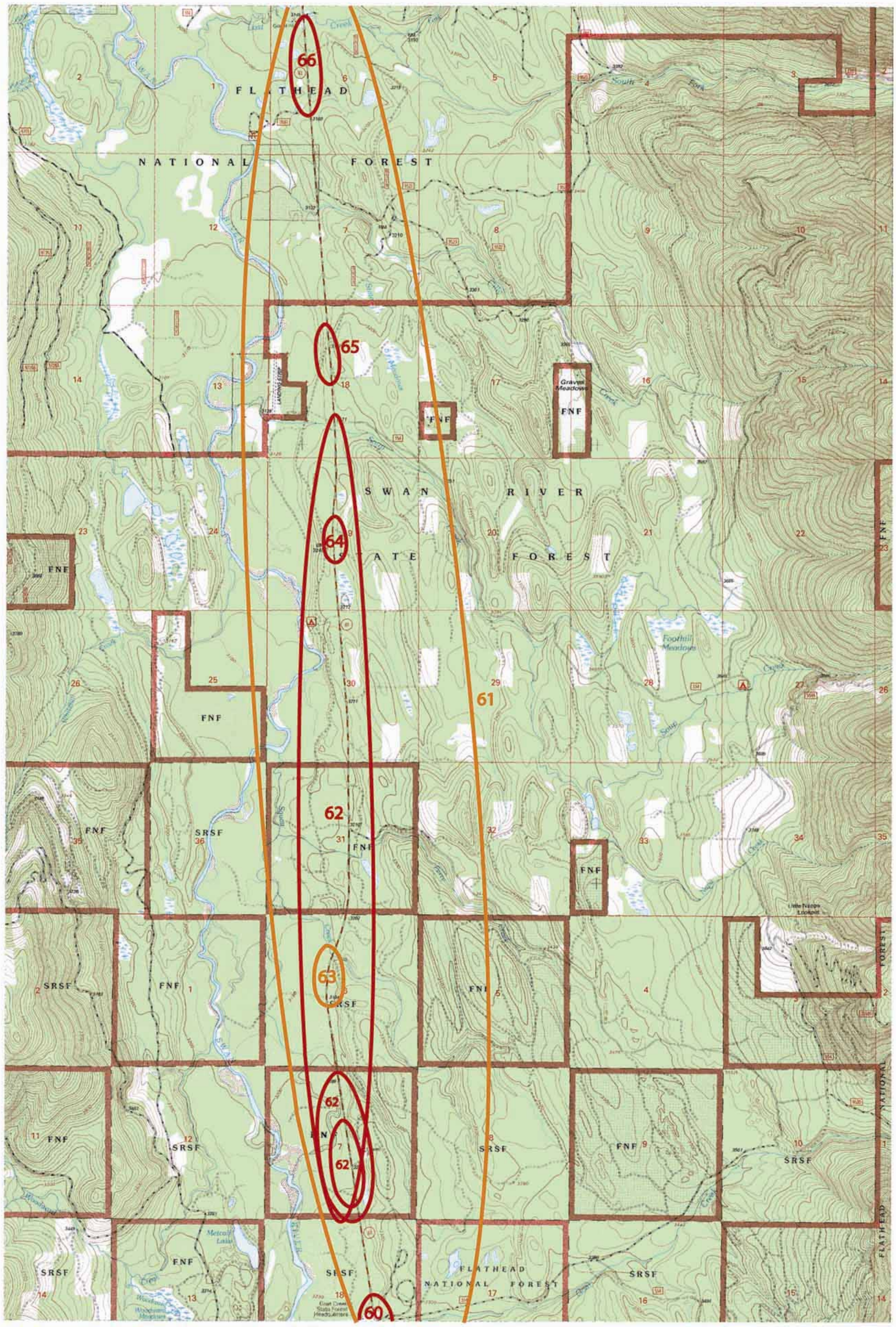
11. Salmon Prairie



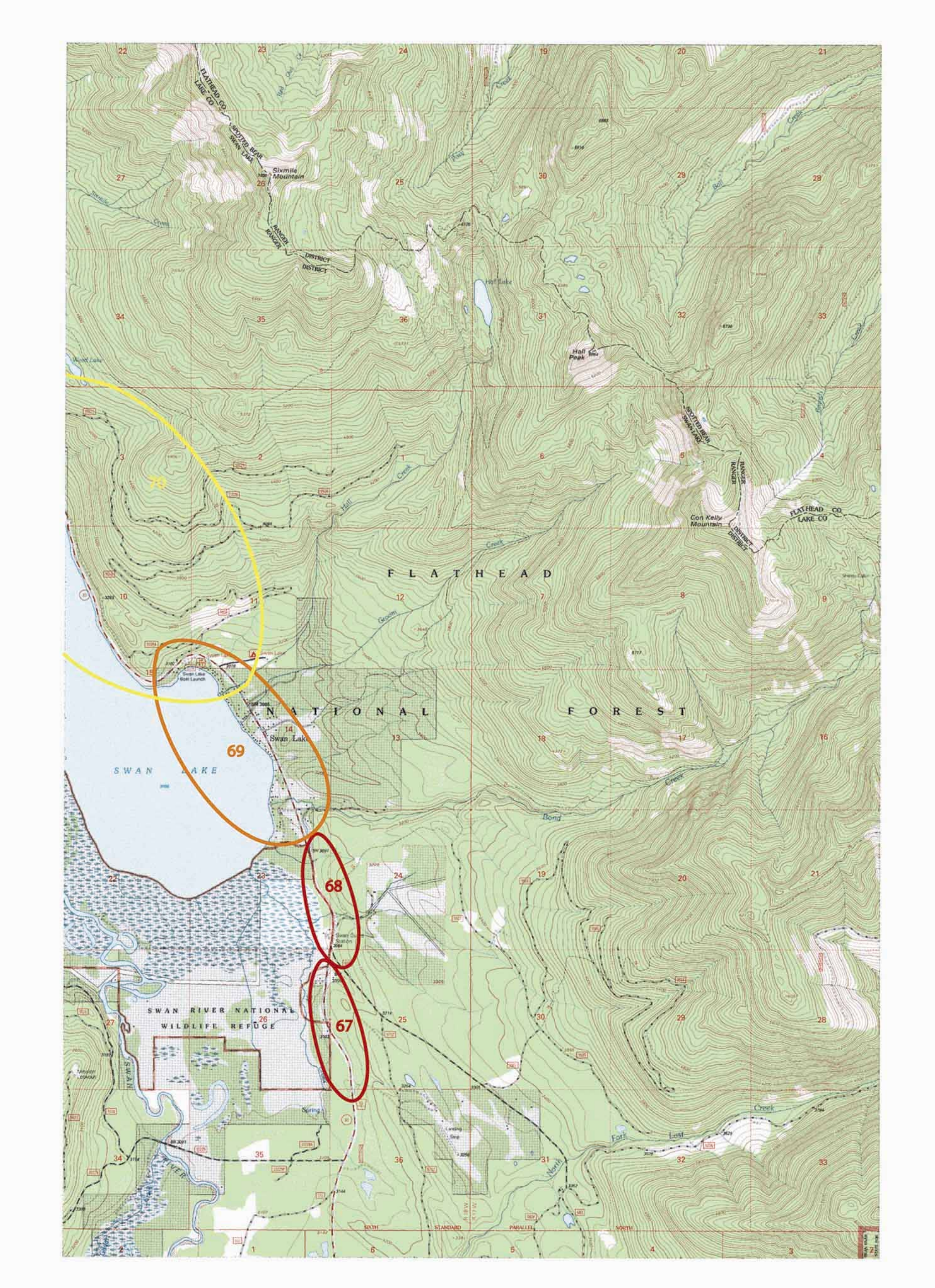
12. Swan Peak


SWAN RIVER
STATE FOREST
SWAN RIVER
STATE FOREST
SWAN
FLATHEAD
NATIONAL
FOREST
RANGE
BOB MARSHALL WILDERNESS
FLATHEAD CO
LAKE CO
Swan Peak
Glaciers
Van Peak
Creek
Lion
Creek
Pony Lake
Union Peak

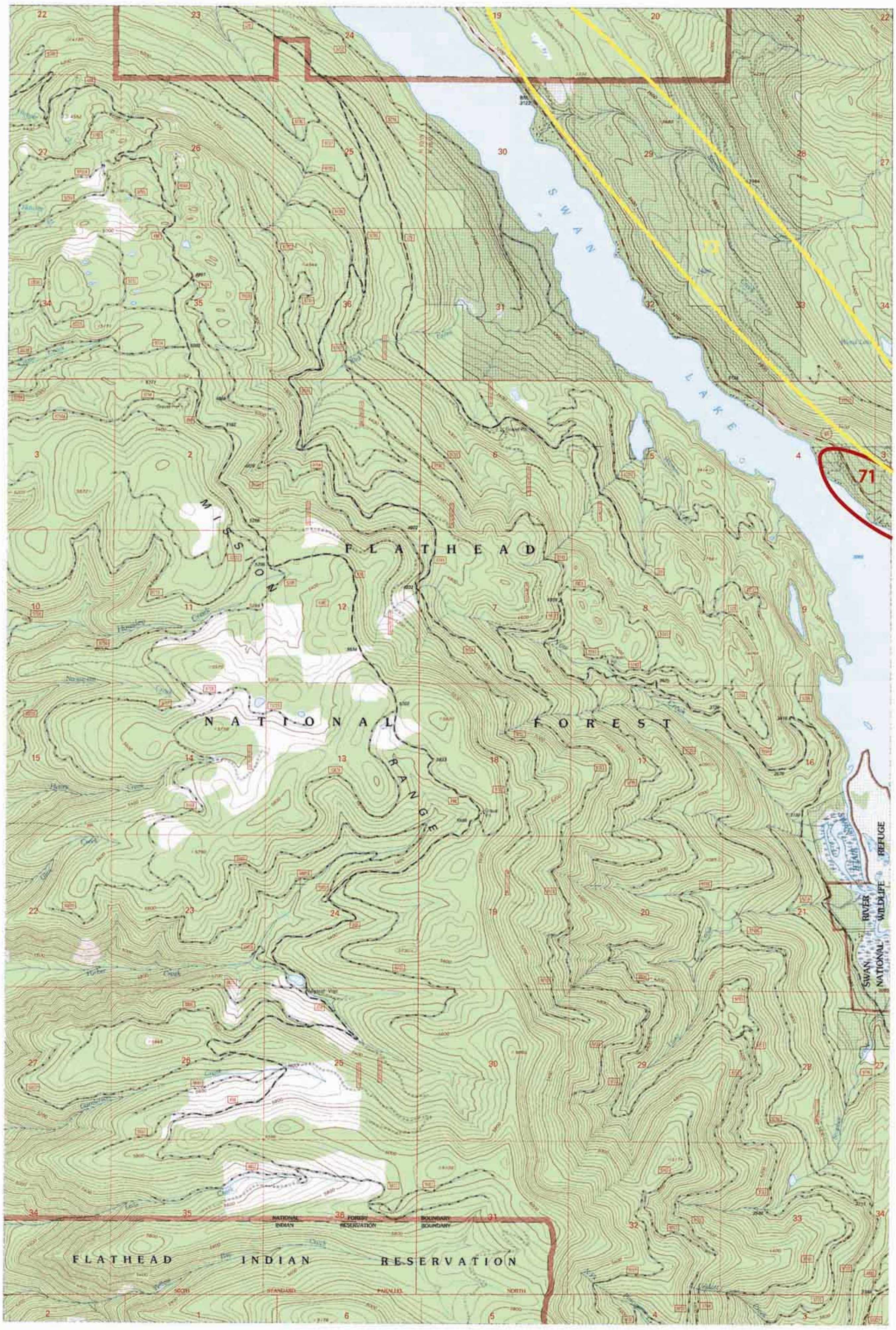
13. Cilly Creek



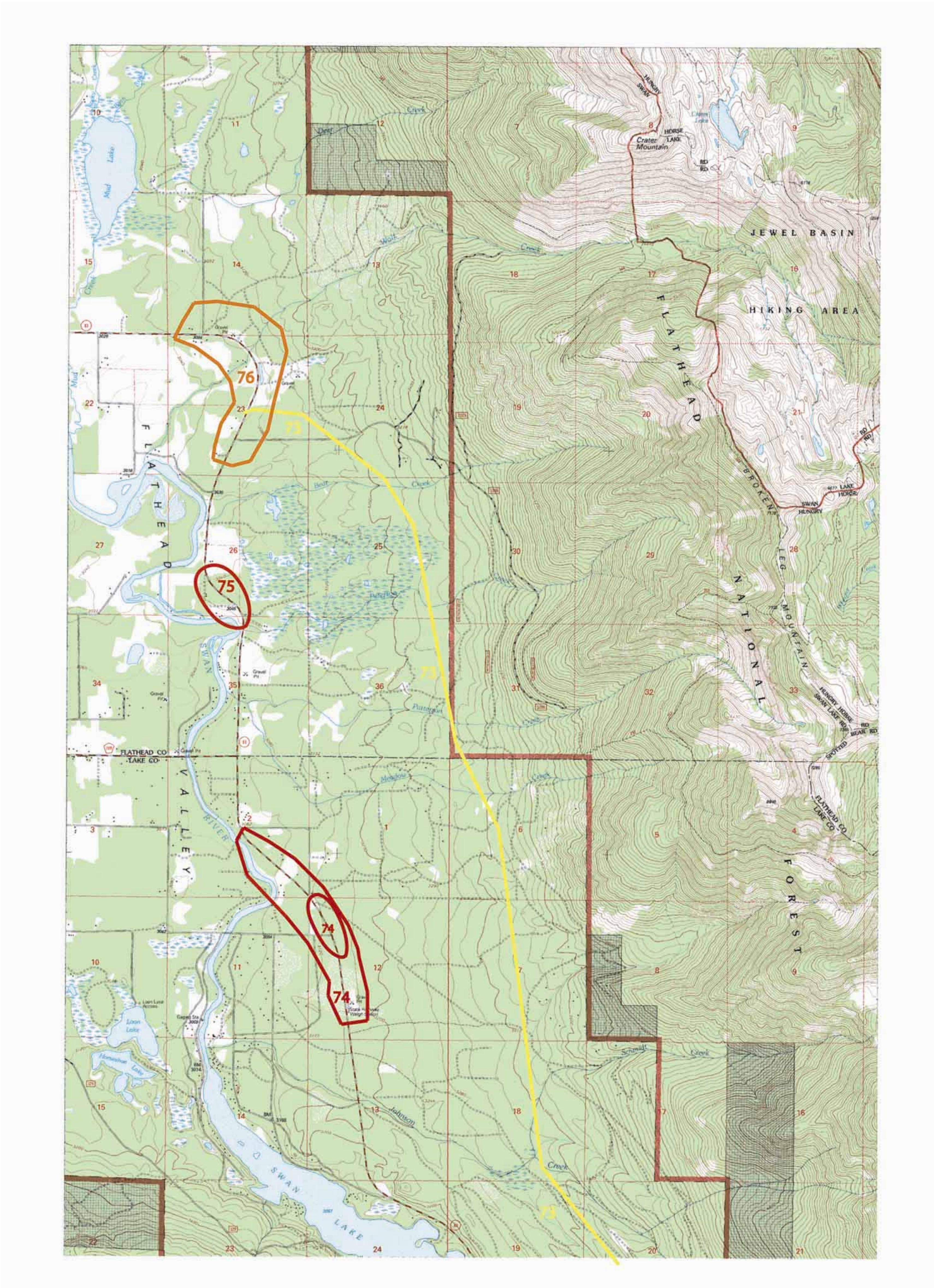
14. Swan Lake


70
69
68
67
F L A T H E A D
N A T I O N A L
F O R E S T
S W A N L A K E
Swan Lake
S W A N R I V E R N A T I O N A L
W I L D L I F E R E F U G E
Sixmile Mountain
Hall Peak
Con Kelly Mountain
FLATHEAD CO
LAKE CO

15. Yew Creek


SWAN LAKE
MISSION RANGE
FLATHEAD NATIONAL FOREST
FLATHEAD INDIAN RESERVATION
SWAN RIVER NATIONAL WILDLIFE REFUGE
71

16. Crater Lake



17. Big Fork


FLATHEAD LAKE
FLATHEAD RIVER
FLATHEAD WATERFOWL PRODUCTION AREA
FLATHEAD LAKE STATE PARK
Bigfork
Holt
Swan River
Ferndale
Woods Bay
Deer Island
FLATHEAD CO
LAKE CO
FLATHEAD NATIONAL FOREST
FNF

APPENDIX E: EXPERT BASED ANIMAL-VEHICLE COLLISION AND HABITAT LINKAGE ZONES

The Oval #'s in the first column relate to the colored ovals on 1:24,000 topographic maps (Appendix D).

Oval # on map, area, map name	Species	Category	Specific comments	Source
#1 Blanchard Flats, Map: Woodworth	Elk, w-t deer, wolf , black and grizzly bear, eagles	Dark red: Important winter and spring range for elk (January-March) and migration route. Collision area, worst in winter and spring. Heavy w-t deer use. Natural movement corridor for other species.	Sometimes a group of elk (up to several hundreds) spend time on the road. Hwy 83 cuts through the Blackfoot-Clearwater Wildlife Management Area at this location. Eagles feed on carcasses and get hit by cars.	Mike Thompson, Jamie Jonkel, Jay Kolbe, Bill Bartlett
#2 N. of Harpers Lake, Map: Salmon Lake	Elk, w-t deer	Dark red: Collision zone continues. It is also a crossing area.	The area is a collision zone all year round, but it is worst in winter and spring.	Mike Thompson
#3 Between Harpers Lake and N. end of Salmon Lake, Map: Salmon Lake	Elk, w-t deer, mule deer, otter, bald eagles	Dark red: Area near Elbow Lake and the whole stretch along Salmon Lake is a collision zone for w-t deer, eagles, elk, and mule deer. It is also an important mule deer crossing area.	Collisions with elk occur mainly in winter and early spring.	Jamie Jonkel, Jay Kolbe, Scott Tomson, Jay Haveman, Bill Bartlett
#4 Prairie Creek, Boyd Mountain, Map: Salmon Lake	A wide range of species, incl. ungulates.	Dark orange: Important linkage zone		Jamie Jonkel, Jay Haveman, Mike Thompson
#5 Boyd Mountain, Map: Salmon Lake	W-t deer, grizzly and black bear, Canada lynx, wolf, eagles, mule deer	Dark red: Travel corridor, road crossings, collision zone.	Mule deer crossings were named explicitly. Salmon lake is a barrier, funneling animal movements to the S. end of the lake.	Jamie Jonkel, Jay Kolbe, Mike Thompson, Jay Haveman, Bill Bartlett

Oval # on map, area, map name	Species	Category	Specific comments	Source
#6 S. end of Salmon Lake, Map: Salmon Lake	W-t deer	Dark orange: w-t deer crossing in spring		Bill Bartlett, Jay Haveman
#7 Salmon Lake area, Map: Salmon Lake	W-t deer, mountain lion	Dark red: Heavy deer kill area, especially in winter. Local and migratory deer populations cross road here.	Mountain lions cross mostly between December-May.	Bill Bartlett, Jay Haveman
#8 N. of Salmon Lake, wetlands, Owl Creek, Map: Salmon Lake	W-t deer, mule deer, elk, grizzly and black bear, beaver, mink, otter, bob cat, mountain lion	Dark red: W-t deer kill area, mule deer crossing. Heavy winter use area.	Wetland on N. end of lake is very important; deer cross here all year round. Other species use the area heavily in winter.	Bill Bartlett, Scott Tomson, Jay Kolbe, Jamie Jonkel, Jay Haveman, Mike Thompson
#9 Poverty Flats, Map: Seeley Lake east	Grizzly bear, elk, w-t deer, and other species	Dark orange: Very important linkage zone, animal movement area	Area links Mission Mountains complex to Horseshoe Hills complex	Jamie Jonkel
#10 Double Arrow southern area, Map: Seeley Lake east	W-t deer, elk, mountain lions, bobcat	Dark red: Heavy w-t deer collision area, other species move through here too.	The wetlands are very important to the animals.	Jay Haveman, Bill Bartlett
#11 Morrell Creek bridge Map: Seeley Lake east	Beaver, mink, otter, bull trout, w-t deer, mountain lion, black bear	Dark red: Important riparian habitat, high collision area for w-t deer	High mortality for w-t deer, all year round, hay fields attract the deer. Black bear cross here frequently too.	Jamie Jonkel, Jay Kolbe
#12 Double Arrow, Poverty Flats, Map: Seeley Lake east	Grizzly bear, elk, mule deer, w-t deer, other species	Dark red: Linkage area, collision zone for w-t deer	Mule deer seasonally, in winter, black bear hit here, hay attracts deer, w-t deer hit all year round	Jamie Jonkel, Jay Haveman, Bill Bartlett , Jay Kolbe
#13 Area above Morrell creek bridge, Seeley Lake east	W-t deer, bear, mountain lion	Riparian habitat, collision zone for w-t deer all year round, winter and spring worse	Hay attracts deer. People feed deer at their houses.	Jay Kolbe, Mike Thompson, Bill Bartlett, Scott Tomson

Oval # on map, area, map name	Species	Category	Specific comments	Source
#14 Seeley Lake, Map Seeley Lake east	Mink, otter, beaver, bear, spawning fish area, w-t deer eagles, other species	Dark orange: Important w-t deer crossing.	The deer cross mostly at Seeley Creek.	Jamie Jonkel, Bill Bartlett
#15 Between Seeley Lake Game Preserve and Seeley Lake, Map: Seeley Lake east	Eagles, black bear, w-t deer	Dark red: Eagles (and presumably w-t deer) collision zone, black bear crossing zone.	Eagles feed on carcasses (presumably deer). Black bears are attracted to campground (food). Timber harvest in this area attracted deer which fed on lichen.	Scott Tomson
#16 near Seeley Lake Ranger Station, Map: Seeley Lake west	W-t deer, elk, mountain lion	Dark red: All year round w-t deer crossing and collision zone, but collisions are worst in winter and early spring. Elk collisions in spring	High density w-t deer population.	Bill Bartlett, Scott Tomson, Tom Parker
#17 near N. end of Seeley Lake, Map: Seeley Lake west	Small carnivores, elk, w-t deer, bears, mountain lions	Dark orange: Heavy animal crossing.	Elk cross occasionally	Tom Parker
#18 Wetlands Clearwater River, Map: Seeley Lake west	Bull trout	Important spawning area		Jamie Jonkel
#19 Sawyer Creek, Map: Seeley Lake west	A wide range of species	Dark orange: Crossing zone.	Dense timber on either side used by a wide range of species.	Bill Bartlett
#20 Benedict Creek Map: Seeley Lake west	Grizzly bear	Dark orange: Crossing zone.	All creeks on map Seeley Lake west are important crossing areas, collared grizzly bear movements here.	Jamie Jonkel

Oval # on map, area, map name	Species	Category	Specific comments	Source
#21 Findell Creek area, Map: Lake Inez	Wide range of species, incl. elk, w-t deer, carnivores	Dark orange: elk migration zone	Topography funnels animal movement (wetlands and ridges), but the degree varies with the seasons.	Jamie Jonkel, Tom Parker, Mike Thompson
#22 Grays Mill, Map: Lake Inez	w-t deer	Dark orange: Spring crossing zone for w-t deer.		Bill Bartlett
#23 Camp Creek area, Map: Lake Inez	Grizzly bear, Canada lynx	Dark red: Carnivore migration area, w-t deer collision zone	Young grizzly bear spotted eating near road, bears use road corridor and feed on w-t deer carcasses.	Jamie Jonkel, Scott Tomson, Jay Kolbe
#24 Area between lake Inez and Lake Alva, Map: Lake Inez	Canada lynx, fisher, wolf, wolverine, grizzly bear, elk, w-t deer, pine marten, bobcat, mountain lion	Dark orange: Corridor for a wide range of species. It is also an elk migration area.	Important animal use and crossing area, grizzly bears use roadsides here in spring and summer, Canada lynx cross hwy to beaver creek, many pine martens in area, logging in area will change small mammal use within this area, riparian areas have abundant cover	Jamie Jonkel, Jay Kolbe, Mike Thompson, Bill Bartlett, Tom Parker, Scott Tomson
#25 Area between Lake Alva and Rainy Lake, Map: Lake Inez	Grizzly bear, black bear, Canada lynx, bob cat, pine marten, mountain lion, w-t deer, elk	Dark orange: Important movement area for a wide range of species.	Heavy bear use, some elk, many other species.	Jamie Jonkel, Tom Parker, Scott Tomson, Jay Kolbe, Bill Bartlett
#26 N of Rainy Lake, Clearwater Rover, Map: Lake Inez	Elk, bear, pine marten	Dark red: Bear habitat, elk migration zone in spring, heavy bear use, presumably w-t deer collision area.	The creek area is very important, bears feed on carcasses.	Jay Kolbe, Jamie Jonkel, Bill Bartlett, Scott Tomson
#27 N. of Rainy Lake, Bertha Creek, Map: Lake Inez	Bear	Green: Important bear habitat.		Jamie Jonkel

Oval # on map, area, map name	Species	Category	Specific comments	Source
#28 area north of Bertha Creek to Summit Lake Map: Lake Inez	W-t deer, pine marten, bear, many other species	Dark red: The summit area is an important animal movement area and a heavy w-t deer collision zone.	A wide range of species cross here from Beaver creek-Lindberg Lake. Habitat and topographic features funnel the animals to this area.	Jamie Jonkel, Scott Tomson, Tom Parker, Jay Kolbe
#29 South of Summit Springs, Map: Lake Inez	W-t deer	Dark red: Collision zone.		Scott Tomson
#30 by Summit Lake, Map: Cygnet Lake	Pine marten, black and grizzly bear	Dark orange: Heavy use zone for bears	Pine marten found here in winter. The area is an emerging problem for bears. Topography guides the bears to this area.	Tom Parker, Bill Bartlett
#31 Pierce Creek, Map: Cygnet Lake	Elk	Dark red: Elk crossing and collision zone.	Elk cross year round, but especially in early spring. A resident elk herd is present throughout the winter. Elk migration pattern has changed over the last 3-4 years.	Scott Tomson, Jay Kolbe
#32 Frey Meadows, Map: Cygnet Lake	Elk, w-t deer, other mammal species	Dark red: Elk crossing and collision zone, especially in early spring. W-t deer collision zone. The small circles were deemed most important within the greater zone.	Elk migration area. W-t deer wander back and forth near Swan River year round. Feeding area in spring. Deer winter here.	Ken Wolff, Anne Dahl, Tom Parker, Scott Tomson, Jay Kolbe

Oval # on map, area, map name	Species	Category	Specific comments	Source
#33 by Gordon Ranch, Map: Cygnet Lake	W-t deer, elk, wolf, mountain lion, grizzly bear, black bear, coyotes	Dark red: W-t deer collision zone, emerging recent animal crossing. Small circles were deemed most important within the greater zone.	The wetlands attract deer. Bear are hit by Holland Lake Road. The Gordon Ranch feeds stock which attracts deer and elk. With heavy snow the deer go south from Swan Valley School (#37) and cross from west to east, down the ridges to the riparian areas. Then they go north.	Tom Parker, Bud Moore, Anne Dahl, Bill Bartlett
#34 S. of Barber Creek, Map: Cygnet Lake	W-t deer	Dark red: Collision zone.	Recent collision zone for w-t deer near Jetty Rd.	Tom Parker
#35 Barber Creek area, Map: Cygnet Lake	Elk	Yellow: Elk winter range area near road.		Anne Dahl
#36 Barber Creek area, Map: Cygnet Lake	Elk, beaver, w-t deer, bobcat, Mountain lion	Dark red: Deer collision zone, elk collision zone. Small circle was deemed most important within the greater zone.	In winter, big elk collision area. Elk travel back and forth for water, cat crossing, beaver killed on road.	Anne Dahl, Tom Parker, Bill Bartlett, Ken Wolff
#37 Swan Valley School, Buck creek, Map: Cygnet Lake	W-t deer, grizzly and black bear, mountain lion	Dark red: Big w-t deer collision zone, w-t deer crossing, bear crossing, elk winter range, elk crossing.	People feed deer. Many w-t deer collisions. The carcasses attract bears that then get hit as well. The elk movement patterns are changing; it is not a historic elk range. Plum Creek land management has led to changes in animal movements. Wetlands on one side and the Swan River on the other make deer cross back and forth.	Ken Wolff, Anne Dahl, Bud Moore, Tom Parker, Bill Bartlett, Scott Tomson

Oval # on map, area, map name	Species	Category	Specific comments	Source
#38 Between Buck Creek and Rumble Creek, Map: Condon	Elk, w-t deer, black and grizzly bear, raven	Dark red: Big collision zone for w-t deer, important elk crossing zone.	Historic and emerging crossing zone for w-t deer. Plum Creek land management and residential development and associated feeding has turned this area into a collision zone, including bears and ravens	Anne Dahl, Tom Parker
#39 Cooney Creek area, Map: Condon	W-t deer	Dark red: Collision area. Small circle was deemed most important within the greater zone.		Anne Dahl, Tom Parker
#40 by fire department Map: Condon	W-t deer	Dark red: W-t deer collision area. Small circle was deemed most important within the greater zone.	People feed the deer, also indirectly by feeding horses, especially in winter.	Anne Dahl, Tom Parker, Ken Wolff
#41 S. of airstrip, town of Condon, Map: Condon	W-t deer, grizzly and black bear, mountain lion, elk	Dark red: W-t deer collision area	Not historically a collision zone, very infrequent use in the past, increased heavy use by w-t deer, animals being funneled along Swan River and wetlands.	Anne Dahl, Bud Moore, Tom Parker
#42 airstrip, Map: Condon	w-t deer	Dark red: Collision zone		Ken Wolff
#43 N. of airstrip, Map: Condon	W-t deer and a wide range of other species	Dark red: Collision zone for w-t deer.	Crossing and collision zone, funnel for wildlife movements.	Ken Wolff, Anne Dahl, Bud Moore, Tom Parker
#44 N. of airstrip, Map: Condon	W-t deer	Dark red: W-t deer collision and crossing zone.		Ken Wolff, Tom Parker

Oval # on map, area, map name	Species	Category	Specific comments	Source
#45 Near Condon Post Office and Mission Mountain Mercantile, Map: Condon	W-t deer, elk, grizzly and black bear, wolf, mountain lion	Dark red: Heavy year round collision area, very important animal corridor. Elk present year round.	Some sources consider this the most important linkage zone in the Swan valley. Plum Creek land management practices (south of Mission Mountain Mercantile and Kaufman road) have resulted cause animals to stay away there and cross here. Open gardens attract ungulates too.	Tom Parker, Anne Dahl, Ken Wolff
#46 Cold Creek road, Map: Condon	w-t deer	Dark red: Collision zone in winter. Small circle was deemed most important within the greater zone.	Increased collision zone in winter due to land management practices on Plum Creek and other private lands.	Tom Parker, Anne Dahl
#47 Condon Creek wetlands, Map: Condon	A wide range of species	Important wetland and riparian area		Anne Dahl
#48 Cold Creek, Map: Peck lake	W-t deer	Dark red: Collision zone.	This is a continuation of Cold Creek collision zone (#46)	Tom Parker
#49 Condon Creek, Map: Peck Lake	Elk	Dark red: Elk crossing and collision zone		Tom Parker, Anne Dahl
#50 Dog Creek area, Map: Peck Lake	W-t deer, turtles	Dark red: Collision area. Small circle was deemed most important within the greater zone.	Wetlands on one side and river on the other. Turtles hit around RP 48 (county line)	Ken Wolff
#51 Swan River, Map: Peck Lake	Elk	Green: Winter range.		Anne Dahl
#52 pony creek Map: Peck Lake	Elk, w-t deer, eagles	Dark red: Collision area. Small circle was deemed most important within the greater zone.	Collisions especially with elk, collisions with eagles in winter.	Ken Wolff, Tom Parker, Anne Dahl

Oval # on map, area, map name	Species	Category	Specific comments	Source
#53 Salmon Prairie area, Map: Salmon Prairie	W-t deer, elk, coyote, fox, bears	Dark red: Collision and crossing area. Smaller circles were deemed most important within the greater zone.	Elk winter range. W-t deer congregate here in winter because this area has relatively little snow. W-t deer are present year round (continuation of #52).	Tom Parker, Anne Dahl, Joe Lawrence, Ken Wolff
#54 Jim Creek area, Map: Salmon Prairie	Elk	Green: Winter range for elk.		Anne Dahl
#55 Map: Salmon prairie	W-t deer, elk, eagles, bear	Dark red: Winter range, crossing and collision area. Smaller circles were deemed most important within the greater zone.	Area covers entire salmon prairie map, from south of Dry Lake to Cilly Creek. This area has good thermal cover. Bad collision area at RP 53. This is a bad collision area for eagles in winter too.	Anne Dahl, Ken Wolff
#56 N. of Lion Creek, Van Lake rd., Map: Salmon Prairie	Elk, w-t deer, wide range of other species	Dark red: Collision zone for w-t deer, animal crossing zone.		Ken Wolff, Anne Dahl, Glen Gray, Tom Parker, Joe Lawrence
#57 Simpson meadows, Map: Salmon Prairie	Light red: W-t deer, pine marten, elk	Light red: Pine marten hit on road. Ungulate winter range.		Ken Wolff, Anne Dahl, Tom Parker
#58 S. of Goat Creek, Map: Salmon Prairie	W-t deer	Dark red: heavy collision zone.	Thousands of w-t deer move through here. It is a winter range and migration area.	Ken Wolff
#59 Goat Creek, Map: Salmon Prairie	W-t deer	Dark red: Winter collision zone.	This area provides thermal cover and there is relatively little snow.	Glen Gray, Joe Lawrence
#60 by Goat Creek, Map: Cilly Creek	W-t deer, Canada lynx	Dark red: Collision and crossing area in winter.	Continuation of Goat Creek collisions zone (#59).	Glen Gray

Oval # on map, area, map name	Species	Category	Specific comments	Source
#61 Entire Cilly Creek map, Map: Cilly Creek	Elk, w-t deer	Dark orange: winter range and crossing area.	Entire map area is winter range to the south end of Swan Lake.	Anne Dahl
#62 Squaw Creek area, Map: Cilly Creek	Elk, w-t deer	Dark red: Migration and collision zone, especially near gravel pit. Collision zone extends up to Soup Creek for w-t deer.	W-t deer frequent this area in spring and summer, elk in spring and fall. It is also on the edge of a winter range for w-t deer (December-April). There are few deer here than.	Glen Gray, Joe Lawrence
#63 Squaw Creek, Map: Cilly Creek	Bear	Dark orange: Crossing zone for bears.		Joe Lawrence
#64 near wetlands, Map: Cilly Creek	W-t deer	Dark red: Crossing and collision zone.	Small wetlands. Salvage logging in this area has influenced deer to cross in high numbers.	Joe Lawrence
#65 State Meadows, Map: Cilly Creek	Elk	Dark red: Elk crossing and collision zone.	Especially between April and December.	Joe Lawrence, Glen Gray
#66 S of Lost Creek, Map: Cilly Creek	Moose	Dark red: Moose collisions.	A few moose have been hit here over the last decade. Moose occur close to road between Lost Creek and Cilly Creek.	Joe Lawrence
#67 near Swan River National Wildlife Refuge, Map: Swan Lake	Many species, incl. snowshoe hare, Black bear, pine marten, bobcat, mountain lion, Canada lynx	Dark red: Collision zone.	Many inlets. Many animals wander along road. W-t deer occur mostly close to cover. Heavy elk use in spring, summer and fall.	Ken Wolff, Joe Lawrence
#68 South of Swan Lake, Map: Swan Lake	W-t deer, elk	Dark red: Collision area.	Many trees along road. This is where many w-t deer cross, especially between April and December.	Ken Wolff, Glen Gray

Oval # on map, area, map name	Species	Category	Specific comments	Source
#69 Town of Swan Lake, Map: Swan Lake	Mule deer, w-t deer	Dark orange: crossing zone.	Many w-t deer have adapted to town living here.	Joe Lawrence
#70 N. of Swan Lake, Map: Swan Lake	W-t deer, mule deer, elk, mountain lion	Yellow: Important winter range for ungulates.		Glen Gray, Joe Lawrence
#71 Weed Hill, Map: Yew Creek	W-t deer, Mountain lion	Dark red: Winter range for deer, collision zone.	A warmer area, many deer use this area year round, but use is heaviest in winter.	Joe Lawrence
#72 Swan Lake, Map: Yew Creek	w-t deer	Yellow: Winter range.	The heavier the snow pack, the more the w-t deer cross the road.	Joe Lawrence
#73 Map: Crater Lake	w-t deer	Yellow: Winter range.	The heavier the snow pack, the more the w-t deer cross the road.	Joe Lawrence
#74 Johnson Creek, Map: Crater Lake	W-t deer, wild turkey	Dark red: Crossing and collision zone. The small circle indicates the heaviest collision area.	Wild turkey collisions occur here.	Joe Lawrence
#75 Peterson Creek, Map: Crater Lake	w-t deer	Dark red: Heavy collision area.		Joe Lawrence
#76 Near gravel pits, Map: Crater Lake	Mule deer	Dark orange: Crossing area.	Mule deer cross road, but are seldom hit.	Joe Lawrence

APPENDIX F: CONTACT DETAILS INDIVIDUALS FOR POTENTIAL FUTURE INTERVIEWS

Name	Affiliation and contact details	Topic
Kirby Adams	Detachment 624, Montana Highway Patrol, 3220 Hwy 93 S Suite 2, Kalispell MT 59901, Dispatch: 800-525-5555	General: location of animal-vehicle collisions.
Chuck Bartos	Active Swan Valley game warden, 51 Riverside Dr., Kalispell, MT 59901, Phone , home, 406-253-2934 (referred to by Ken Wolff)	
Doug Channke	University of Montana	Deer study Clearwater area
Joel Cahoon	Civil Engineering Department, 220 Cobleigh Hall, room 205, Montana State University, Bozeman, Montana MT, 59717-3900, Phone: 406 994-5961, joelc@ce.montana.edu	Fish passages
Bill Koppen	Game warden for the Seeley Lake area, Region 2, Missoula, PO Box 402, Seeley Lake, MT 59868,Phone: 406-677-3628, cell 210-1299, home 244-3628 (referred to by Jay Kolbe).	General: location with high-frequency animal-vehicle collision areas, high frequency animal crossing areas, changes in land use and management.
Kerry Foresman	Professor of Biology and Wildlife Biology, University of Montana, Missoula, MT., Phone: 406-243-4492, foresman@selway.umt.edu	Wildlife crossings south of Salmon Lake.
Tabitha Graves	The University of Montana, College of Forestry and Conservation, Missoula, MT 59812, Phone: 406-243-5197, Office: UH 309, tabitha.graves@umontana.edu	Grizzly bears.
Kate Kendall	USGS-NRMSC, Science Center, c/o Glacier National Park, West Glacier, Montana 59936-0128, phone: 406-888-7994, kkendall@usgs.gov	Grizzly bears.
Rick Mace	Research Biologist, Montana Fish, Wildlife & Parks, Kalispell, 490 North Meridian Road, Kalispell, MT 59901, 406- 751-4583, rmace@state.mt.us	Bears. Was not able to give a full interview during phase 1.
Scott Mills	Associate Professor of Wildlife Population Ecology, University of Montana, Missoula, MT 59812, Phone: (406) 243-5552 · Office: FOR 307, smills@forestry.umt.edu	Canada lynx and snowshoe hare.
Bob Parcell	Sheriff (Swan valley)	General: location of animal-vehicle collisions.
Bill Potter,	EbarL ranch, individual with local knowledge and experience (referred to by Jay Haveman)	General: location with high-frequency animal-vehicle collision areas, high frequency

Name	Affiliation and contact details	Topic
		animal crossing areas, changes in land use and management.
Chris Servheen	Adjunct Research Associate Professor Wildlife Conservation, Grizzly Bear Recovery Coordinator, University of Montana, Missoula, MT 59812, Phone: (406) 243-4903 · Office: UH 309, grizz@selway.umt.edu	Bears
.John Squires	Research Wildlife Biologist, Forestry Sciences Lab USDA Forest Service – RMRS, 800 Block East Beckwith, P.O. Box 8089, Missoula MT 59807, Phone: 406-542-4164, jsquires@fs.fed.us	Canada lynx
Mike Quinn	retired game warden Swan Valley, Region 1 Kalispell. PO Box 1095, Bigfork, MT 59911, Phone, home 406-755-2614 (referred to by Glen Gray)	General: location with high-frequency animal-vehicle collision areas, high frequency animal crossing areas, changes in land use and management.

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