Teton County Wildlife Crossings Master Plan

by

Marcel P. Huijser, PhD[1]
Corinna Riginos, PhD[2]
Matt Blank, PhD[1]
Rob Ament, MSc[1]
James S. Begley, MSc[1]
and Edward R. Jenne, BSc[3]

[1]Western Transportation Institute, Montana State University
[2]Northern Rockies Conservation Cooperative
[3]E.R. Jenne Illustration

FINAL REPORT

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

A report prepared for
Teton County
320 S. King Street, Jackson,
Wyoming 83001, USA

May 31, 2018

DISCLAIMER

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

ACKNOWLEDGEMENTS

The authors of this report would like to thank Teton County for funding this project. Special thanks are due to the following organizations and individuals who have provided data or other information. Their contributions have been critical to the project's success.

- Chris Colligan (Greater Yellowstone Coalition)
- Alyson Courtemanch (Wyoming Game & Fish Department)
- Keith Compton (WYDOT)
- Gary Fralick (Wyoming Game & Fish Department)
- Morgan Graham (Teton Conservation District)
- Susan Johnson (Teton County)
- Jon Mobeck (Jackson Hole Wildlife Foundation)
- Sean O'Malley (Teton County)
- Darin Martens (US Forest Service)
- Amy Ramage (Teton County)
- Siva Sundaresan (first: Jackson Hole Conservation Alliance; later: Greater Yellowstone Coalition)
- Leslie Steen (Trout Unlimited)
- Marisa Wilson (Jackson Hole Conservation Alliance)
- Leah Zamesnik (Jackson Hole Conservation Alliance)

Many thanks also to the following people and organizations for their contributions:

- Bob Bonds (WYDOT)
- Eric Cole (US Fish & Wildlife Service)
- Sarah Dewey (Grand Teton National Park)
- Carlin Girard (Teton Conservation District)
- Rob Gipson (Wyoming Game & Fish Department)
- Paul Hood (Nature Mapping Jackson Hole/Jackson Hole Wildlife Foundation)
- Brad Hovinga (Wyoming Game & Fish Department)
- Matt Kauffman (Wyoming Migration Initiative)
- Kyle Lash (Wyoming Game & Fish Department)
- Doug McWhirter (Wyoming Game & Fish Department)
- Diana Miller (Wyoming Game & Fish Department)
- Anna Senecal (Wyoming Game & Fish Department)
- Jon Stephens (Wyoming Game & Fish Department)
- Ben Wise (Wyoming Game & Fish Department)

TECHNICAL DOCUMENTATION

1. Report No. 4W6693	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Teton County Wildlife Master Plan		**5. Report Date** May 2018 **6. Performing Organization Code**
7. Author(s) Marcel P. Huijser, Corinna Riginos, Matt Blank, Rob Ament, James S. Begley, and Edward R. Jenne		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Western Transportation Institute P.O. Box 174250 Montana State University Bozeman, MT 59717-4250		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** 4W6693
12. Sponsoring Agency Name and Address Teton County 320 S. King Street, Jackson, Wyoming 83001, USA		**13. Type of Report and Period Covered** Research report 4 October 2016 – 31 December 2017 **14. Sponsoring Agency Code**
15. Supplementary Notes A PDF version of this report is available from WTI's website at www.westerntransportationinstitute.org		
16. Abstract This report contains information and tools that identify high priority road sections in Teton County, Wyoming, that qualify for the potential implementation of mitigation measures for wildlife and aquatic species. The measures are aimed at reducing wildlife-vehicle collisions with large mammals, providing safe crossing opportunities for large mammals, and making stream crossings passable for fish species. Note that this report and the drawings are not an official planning or zoning document. The suggested mitigation measures should not be mistaken for actions that must happen exactly as described. Rather, the authors of this report suggest that the human safety, biological conservation, and economic information summarized in this report should be used to understand the why certain highway sections are important to mitigate, what species the mitigation measures should be targeted at, and what those mitigation measures could look like. However, the exact location, length or number, or type and dimensions of the mitigation measures is dependent on public support, agreements with private landowners and land management agencies, and the availability of funding.		
17. Key Words animal detection systems, collisions, corridors, crashes, crossing structures, cost-benefit analysis, data analysis, fences, habitat, highway, hotspot identification, Jackson, Jackson Hole, mitigation, overpasses, plan, procedures, prioritization, ranking, safety, strategy, strategies, Teton County, tools, underpasses, wildlife, wildlife–vehicle collisions, Wyoming	**18. Distribution Statement** Unrestricted. This document is available through Teton County and WTI-MSU.	
19. Security Classification (of this report) Unclassified	**20. Security Classification. (of this page)** Unclassified	**21. No. of Pages** 262 / **22. Price**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Teton County is part of the Greater Yellowstone Ecosystem, a uniquely intact ecosystem that is home to abundant and diverse wildlife species. At the same time, Teton County's human population, and its commuting workforce, have been growing rapidly, at times coming into conflict with wildlife. One consequence of human population and commuter increase is rising traffic volume and associated ecological impacts of roads. Roads can have a variety of impacts on wildlife species, including direct mortality (e.g. when animals get hit by cars), acting as partial or complete barriers to animal movements (both terrestrial and aquatic species), and reducing the habitat that is effectively available to wildlife. Vehicle collisions with large mammals also pose a substantial human safety problem and associated economic impact.

Protecting wildlife populations is a central community value, as reflected in the Teton County Comprehensive Plan. Specifically, Plan policies 1.1.c and 1.4.d identify maintaining wildlife habitat connectivity and safe wildlife highway crossings as priorities. At present, however, there is no comprehensive plan for how to achieve this goal in Teton County. This report is at the request from Teton County for a Wildlife Crossings Master Plan. The Wildlife Crossings Master Plan sets priorities based on human safety, economics, and biological conservation parameters. It identifies suitable mitigation measures given the context of the individual sites. The purpose of this report is to provide Teton County with information and tools that identify high priority road sections that qualify for the potential implementation of mitigation measures for large wild mammals and aquatic species. The measures are aimed at reducing wildlife-vehicle collisions with large mammals, providing safe crossing opportunities for large mammals, and making stream crossings passable for fish species.

The literature review in this report describes the effectiveness of wildlife warning signs and the reduction of posted speed limits as these two types of mitigation measures are often suggested to reduce wildlife-vehicle collisions. However, standard wildlife warning signs (black on yellow) and enhanced wildlife warning signs (non-standard, text, symbols, flags, permanently flashing amber lights, variable message signs) are not effective in reducing wildlife-vehicle collisions. They may still serve other purposes such as addressing liability concerns and informing the public about the problem, but if the objective is to reduce wildlife-vehicle collisions, other measures are required. Only wildlife warning signs that are specific in time and place (i.e. seasonal wildlife warning signs and animal detection systems) reduce wildlife-vehicle collisions. While there is some reduction in collisions with seasonal wildlife warning signs (9-50%), the reduction in collisions with animal detection systems can more substantial (33-97%). Lower vehicle speed reduces the stopping distance and can reduce wildlife-vehicle collisions. However, even with a vehicle speed of about 45 mi/h, the limited range of most vehicle's headlights only allows about half the drivers to stop in time for a large animal in the dark. Most highways are designed for much higher speed (e.g. 65 mi/h), and reducing the posted speed limit to a speed that is much lower than the design speed of a highway leads to a mixture of slow- and fast-moving vehicles on the same highway. This phenomenon is referred to as speed dispersion and is associated with an increase in crashes, e.g. because of irresponsible overtaking. Therefore, reducing the posted speed limit to a speed that is low enough to allow a substantial portion of the drivers to potentially stop in time for a large mammal on the highway is only a responsible measure for roads that have a low design speed to begin with. Wildlife fences in combination with wildlife crossing structures (underpasses and overpasses) are the most robust mitigation measures that can reduce collisions with large wild mammals by 80-100% and that allow wildlife to cross the highway safely. However, the fences need to cover substantial road lengths (at least 3 miles long), and they need to be implemented along the entire collision hotspot and also include adjacent buffer zones.

The researchers used existing data on large-mammal-vehicle collisions to identify road sections that have a concentration of wildlife-vehicle collisions. The researchers had access to three data sets: wildlife-vehicle crash data collected by law enforcement personnel, carcass removal data collected by Wyoming Department of Transportation personnel, and a combination of all known sources for large-mammal-vehicle collisions maintained by Jackson Hole Nature Mapping / Jackson Hole Wildlife Foundation. Broadway through the town of Jackson, and the road section at the south end of Jackson have the greatest concentration of large mammal-vehicle collisions. Species specific data showed that mule deer are the most frequently reported species in wildlife-vehicle collisions. Mule deer are most frequently hit in Jackson (Broadway) and along several sections of US Hwy 26/89/191 between the south end of Jackson and Hoback Jct, and along US Hwy 89/26 just west of Hoback Jct. Elk are most frequently hit along US Hwy 26/89/191 south of Jackson (just south of Jackson and Game Creek area), US Hwy 189/191 east of Hoback Jct, along US Hwy 26/89/191 north of Jackson (adjacent to the National Elk Refuge), and along WY 22 near the Teton Science School. Moose are most frequently hit along WY 22 and WY 390 near the Snake River, and along WY 22 west of Teton Pass (near Hungry Creek Rd).

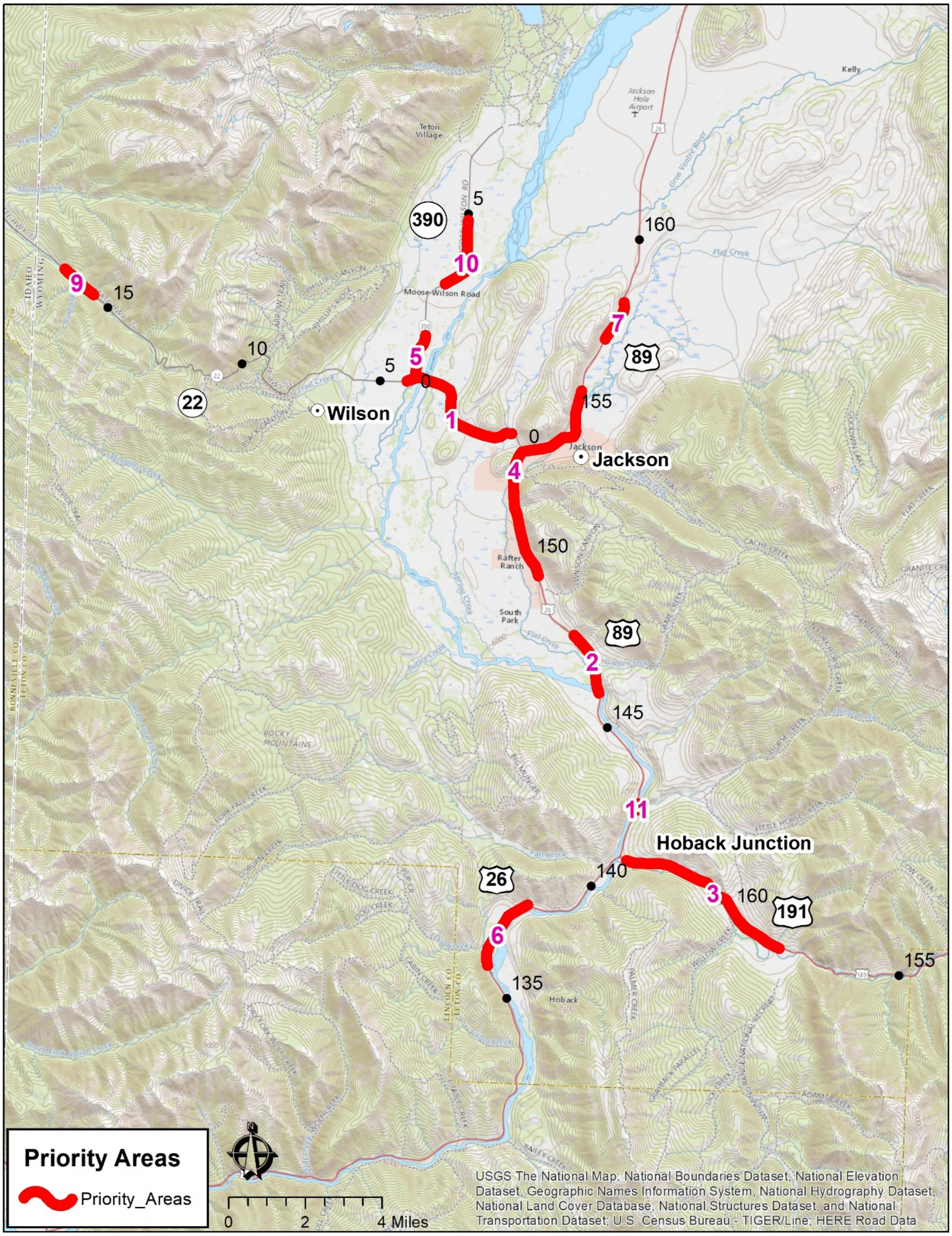
The researchers also used existing data on migration routes, and important habitat for large ungulates and selected species that are considered of greatest concern to biological conservation in Teton County. A substantial portion of the highways in Teton County cut across important migration corridors and habitat for mule deer and elk. Moose habitat and movements are known to occur east of Moran Jct, Along WY 22 and 390 close to the Snake River, and along the ridge at the Teton Science School and the Sky Line Ranch. Bighorn sheep are known to be on US Hwy 189/191 near Camp Creek. High elevation areas along WY 22 (west of Wilson) and US Hwy 26/287 (Togwotee Pass) were identified as important for rare large carnivores.

The researchers calculated the costs associated with large mammal-vehicle collisions along the highways in Teton County based on an existing cost-benefit model. The costs were calculated and compared to the economic thresholds that need to be met for different types and combinations of mitigation measures to pay for themselves. The following highway sections have the highest costs associated with large wild mammal-vehicle collisions and would thus have the greatest economic benefits of implementing mitigation measures aimed at reducing collisions and providing safe crossing opportunities:

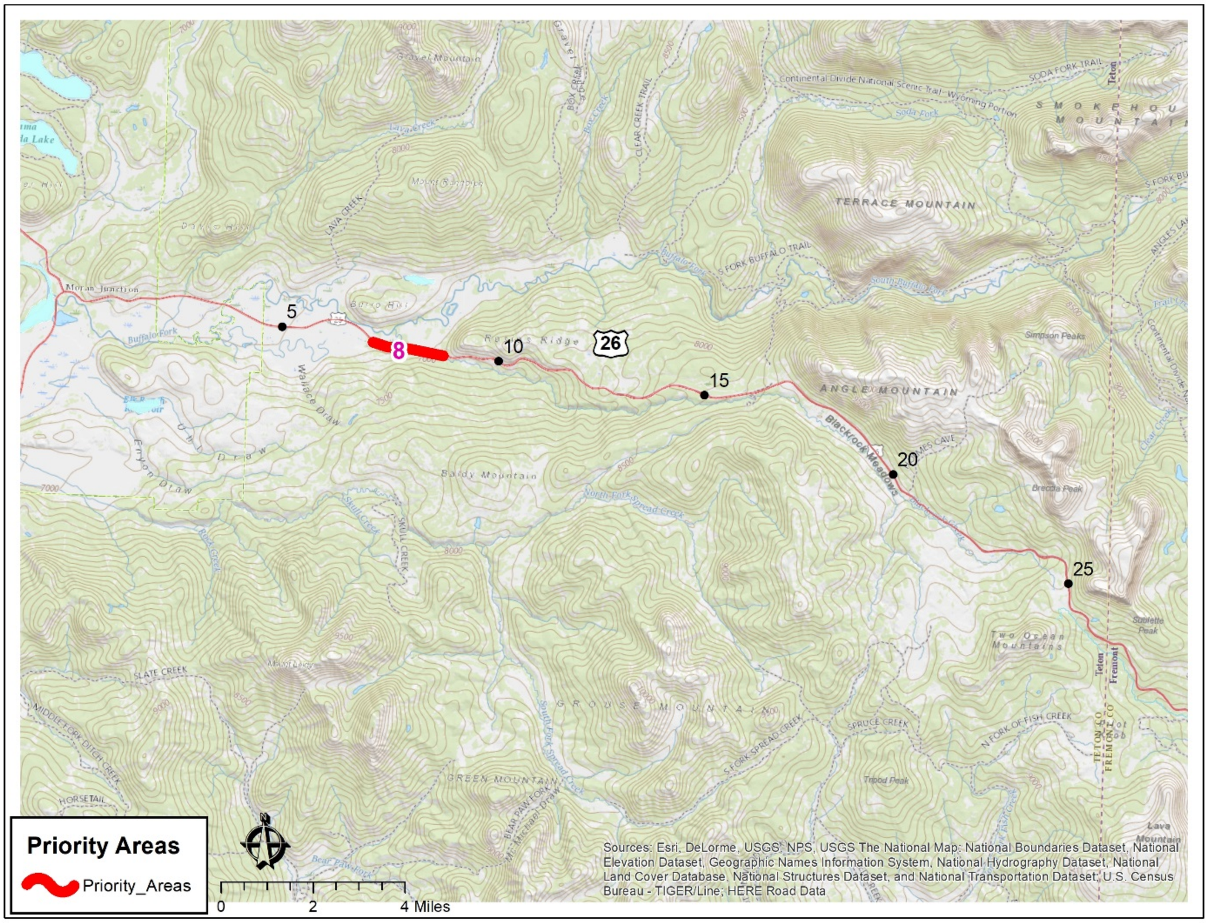
- US Hwy 26/89/191 South end South Park Loop Rd - Jackson (Broadway).
- US Hwy 26/89/191 Snake River- Game Creek area.
- US Hwy 26/89/191 near Fish Hatchery.
- WY 22: Spring Gulch - west of Bar Y Rd.
- WY 22: Jct with WY 390.
- WY 22: Between weigh station and Trail Creek Campground.
- WY 390: Jct WY 22 – Andersen Ln.

The researchers applied a two-step process to rank the road sections in Teton County for the potential implementation of mitigation measures aimed at reducing large mammal-vehicle collisions and providing safe crossing opportunities for large mammals: Step 1: Rank road sections based on human safety/economics and biological conservation individually. Step 2: Rank road sections based on a combination of human safety/economics and biological conservation (equal weight to both). Based on the ranking process the following road sections had the highest priority ranking (see figures and table on next pages).

The researchers provided a rationale for different types and combinations of mitigation measures depending on the design speed of the different highways, traffic volume, the wildlife species at which the mitigation measures are targeted, and the topography. For highways with low design speed (e.g. 45 mi/h) low posted speed limits (e.g. 35-45 mi/h) allow about half of the drivers to stop in time for a large mammal in the dark. For highways with high design speed (e.g. 55 or 65 mi/h) and high traffic volume (e.g. 10,000 vehicles per day and up) the researchers suggest fences or retaining walls to keep large animals off the pavement and wildlife crossing structures to provide safe passage for wildlife. While large underpasses are appropriate for mule deer, elk and moose have far higher use of overpasses. The researchers suggest exploring the possibility of experimental at-grade crossing opportunities, potentially at gaps in a wildlife fence, potentially with animal detection systems for low volume roads (about 1,500-5,000 vehicles per day). However, wildlife fences in combination with wildlife overpasses and underpasses are the most robust mitigation measure, even for low volume roads.



Jackson area



Togwotee Pass

Description road section	Hwy section	Hwy number	Start m reference post	End mi reference post	Length (mi)	Rank	Target species	Recently reconstructed?	Recently mitigated?	Fences/barrier walls	Overpass	Underpass	At-grade	Improved street lighting	Low posted speed limit
Spring Gulch - Jct WY 390	6	22	0.6	4.3	3.8	1	Mule deer, elk, moose	No	No	Yes	2	5		No	
Snake River - Game Creek area	3	S 89	146.0	147.7	1.8	2	Mule deer, elk	Yes	Yes	Recently mitigated					
Camp Creek area - Hoback Jct	1	191	158.4	163.3	5.0	3	Mule deer, elk, bighorn sheep	No	No	Yes	5*		5*	Yes*	
South Park Loop (south end) - Jackson	3/ 4	S/N 89	149.6	155.7	6.2	4	Mule deer, elk	No	No	Yes	2			Yes	
Jct Hwy 22 - N Lily Lake Lane	7	390	0.0	1.2	1.3	5	Moose	No	No	Yes		1		No	Yes
Dog Creek - Hoback elk feed ground area	2	26	136.0	138.0	2.1	6	Mule deer, elk	No	No	Yes	2*		2*	Yes*	
Fish Hatchery	4	N 89	157.2	158.3	1.2	7	Mule deer, elk	No	No	Yes	1	1			
Blackrock Ranger Station area	5	26	7.2	8.8	1.7	8	Moose, Elk, Large carnivores	Yes	No	Recently locally mitigated					
Weigh Station area	6	22	15.5	16.5	1.1	9	Moose, Large carnivores	No	No	Yes	1*		1*	Yes*	
Wilderness Dr - Snake River Ranch Rd	7	390	2.8	4.8	2.1	10	Mule deer, moose	No	No	No					Yes
Horse Creek area	3	S 89	142.5	142.5	0.1	11	Mule deer, elk	Yes	Yes	Recently mitigated					
Total					26.4						5-13*	7	8*		

*Note that wildlife fences and wildlife crossing structures (especially overpasses for elk) are the preferred option over at grade crossing opportunities (with or without lighting).

The researchers also investigated the effectiveness of reduced night time speed limit along the first 4 miles of WY 390 from the Jct with WY 22. This road section had the night time speed limit lowered from 45 mi/h to 35 mi/h in 2012. The daytime speed limit remained at 45 mi/h. While there currently is no detectable benefit of the night time speed limit reduction along WY 390, it would be wrong to conclude that vehicle speed is not an important factor for wildlife-vehicle collisions. Higher vehicle speeds do result in longer stopping distance (see Chapter 2). In this chapter we only showed that reducing an already low posted speed limit (45 mi/h) to an even lower speed limit (35 mi/h) did not result in a significant reduction in collisions with large wild animals. The design speed of WY 390 is low as it is (especially in the curvy southern section with limited sight distances) and keeping the speed limits low along WY 390 is likely to result in fewer wildlife-vehicle collisions compared to increasing the speed limit. However, in general, reducing posted speed limits substantially below the design speeds of highways is potentially dangerous to human safety and should be avoided. Speed management as a tool to reduce wildlife-vehicle collisions is limited to roads that have a low design speed.

Based on the literature review on roads and streams in this report, the best approach to protect aquatic habitat and connectivity is to ensure the roads are constructed a sufficient distance from them or, in retrofit situations, to move the road to avoid interfering with it. If avoidance is not feasible, which is often the case, then the next best approach is to create a sufficient natural or semi-natural buffer between the road and the habitat. A well-designed and constructed buffer will capture, store and process pollutants prior to them entering a waterbody. The width of the buffer will vary depending on the features of the landscape such as type of vegetation, soils and slope, as well as the volume and characteristics of the storm water. Should stream crossings be required, long-span bridges that are wide enough to allow for full floodplain function through them allow for the natural function of the stream or river and riparian area. These types of structures will also provide connectivity for both terrestrial and aquatic species. However, long-span bridges are also the costliest option for road-stream crossings which can in some cases make them infeasible. Other large structures that fully span the stream or river and its banks provide the next best solution to ensure long-term passage of fish and aquatic species, and are less expensive than long-span structures like bridges. In retrofit cases, it may be more feasible to remove the existing infrastructure and reinstate the natural system or replace it with a crossing structure designed using a “stream-simulation” approach. The stream-simulation approach relies upon the basic principle that the stream dynamics should be as similar as possible to the natural channel. In some situations, such as retrofit scenarios, baffles can be installed within the culvert barrel to increase water depth, decrease velocity and increase velocity diversity to reduce the barrier effect of the stream crossing to aquatic organisms.

The researchers provided “high-level” general design recommendations for replacing existing stream crossings with new structures. The researchers reached out to key stakeholders to gather existing information about road-stream crossing structures in Teton County, the aquatic habitats they cross, hydrology and geomorphology of the counties’ rivers and streams, and fisheries. Site visits were conducted at ten stream crossings representing a range of different road-stream crossings to gain a better understanding of site-specific and regional issues, and to get a clearer idea of the physical and biological setting. The information was used to develop general or “high-level” mitigation measures or strategies with a focus on providing long-term aquatic connectivity moving forward. The researchers also integrated mitigation strategies for terrestrial and semi-aquatic wildlife at stream crossings (e.g. riparian and terrestrial habitat). This integration was very important as one structure can address the barrier effect of a road and associated traffic for both aquatic and terrestrial species.

The researchers provided conceptual drawings that illustrate the design principles and design concepts of mitigation measures to reduce collisions with large mammals, to provide safe crossing opportunities for wildlife, and to provide stream crossings that are passable to native aquatic species. Note that this report and the drawings are not an official planning or zoning document. In addition, the drawings are not necessarily tied to a specific parcel, but they do relate to recognizable road sections. The suggested mitigation measures should not be mistaken for actions that must happen exactly as described. Rather, the authors of this report suggest that the human safety, biological conservation, and economic information summarized in this report should be used to understand the why certain highway sections are important to mitigate, what species the mitigation measures should be targeted at, and what those mitigation measures could look like. However, the exact location, length or number, or type and dimensions of the mitigation measures is dependent on public support, agreements with private landowners and land management agencies, and the availability of funding.

Teton County organized a public meeting on Wednesday July 19th 2017, 4-7 pm at the Teton County library auditorium, 125 Virginian Lane, Jackson, Wyoming. Posters illustrating the problems with wildlife and highways and streams and highways and draft potential solutions were displayed in the meeting room. Dr. Marcel Huijser provided a podium presentation on wildlife and highways. There was a question and answer session with the public after the presentation. In addition, the public was asked to provide written comments on the posters, including the draft mitigation measures.

Finally, the researchers provided recommendations for the monitoring of wildlife mitigation measures. Emphasis was put on formulating testable research questions that guide the study design. Typical questions are formulated around the effectiveness of mitigation measures in collision reduction and the effectiveness of safe crossing opportunities in providing connectivity for wildlife.

1. INTRODUCTION

1.1. Background

Teton County is part of the Greater Yellowstone Ecosystem, a uniquely intact ecosystem that is home to abundant and diverse wildlife species. At the same time, Teton County's human population, and its commuting workforce, have been growing rapidly, at times coming into conflict with wildlife. One consequence of human population and commuter increase is rising traffic volume and associated ecological impacts of roads. Roads can have a variety of impacts on wildlife species, including direct mortality (e.g. when animals get hit by cars), acting as partial or complete barriers to animal movements (both terrestrial and aquatic species), and reducing the habitat that is effectively available to wildlife (e.g., Huijser & Bergers, 2000; Proctor, 2003; Huijser et al., 2007a). Vehicle collisions with large mammals also pose a substantial human safety problem with substantial economic impacts (Conover et al, 1995; Huijser et al., 2008; Huijser et al., 2009).

Protecting wildlife populations is a central community value, as reflected in the Teton County Comprehensive Plan (Teton County, 2012). Specifically, Plan policies 1.1.c and 1.4.d identify maintaining wildlife habitat connectivity and safe wildlife highway crossings as priorities. At present, however, there is no comprehensive plan for how to achieve this goal in Teton County. This report is at the request from Teton County for a Wildlife Crossings Master Plan. The Wildlife Crossings Master Plan sets priorities based on human safety, biological conservation, and economic parameters, identifies suitable mitigation measures given the context of the individual sites, and provides cost estimates for effective and safe wildlife crossings in Teton County.

1.2. Project Goal and Approach

The goal of the project is to provide Teton County with information and tools that identify high priority road sections that qualify for the potential implementation of mitigation measures for wildlife and aquatic species. The measures are aimed at reducing wildlife-vehicle collisions with large mammals, providing safe crossing opportunities for large mammals, and making stream crossings passable for fish species.

For reducing wildlife-vehicle collisions with large mammals and providing safe crossing opportunities for large mammals the project focused on seven Federal and State highway sections (Figure 1). However, for stream crossings the project also included county roads. The following road sections were excluded from site-specific reviews and recommendations for mitigation measures:

- US Hwy 26/287 east of Moran Jct Togwotee Pass (recently locally mitigated)
- US Hwy 26/89/191 Hoback Jct - South end of South Park Loop Rd (recently mitigated)
- US Hwy 26/89/191 mile reference post 158.8 - Gros Ventre River (adjacent to Grand Teton National Park (west side of the highway).

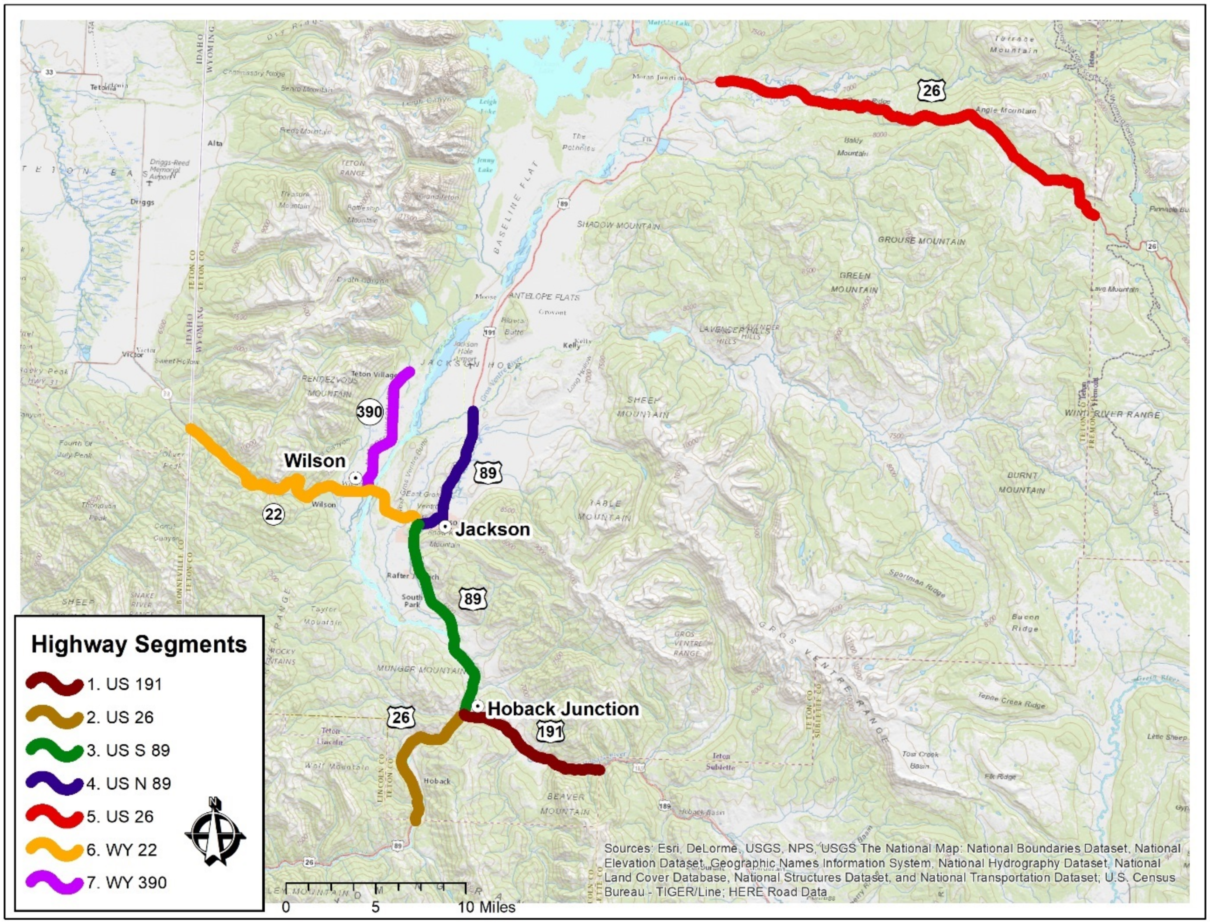


Figure 1: The roads in Teton County, Wyoming, that were included in this project.

The researchers developed a step-wise approach based on existing data, a field review of selected sites along the road sections described in the Request for Proposals, and cost-benefit analyses for the suggested measures. The researchers coordinated with the Advisory Group from Teton County and also asked for input from additional stakeholders, including representatives of Wyoming Department of Transportation, Wyoming Game and Fish, U.S. Fish and Wildlife National Elk Refuge, U.S. Forest Service, Grand Teton National Park, Teton County, Teton Conservation District, Trout Unlimited, Greater Yellowstone Coalition, Jackson Hole Conservation Alliance, and Nature Mapping Jackson Hole/Jackson Hole Wildlife Foundation, Wyoming Migration Initiative. In addition, Teton County organized a public meeting in Jackson at which the researchers illustrated the impacts of roads and traffic on large mammals and fish species in Teton County, discussed potential solutions with the public, and sought their feedback. Conceptual and technical drawings were provided to the public to illustrate a range of potential solutions for selected road sections to help stakeholders and members of the public visualize potential solutions.

1.3. Project Tasks

The tasks for the project are listed below. The tasks are addressed in the following chapters.

Task 1. Conduct a literature review and synthesize and summarize the impacts to wildlife and habitat connectivity caused by roads in Teton County.

Task 2. Develop and describe the methodology used to identify and set priorities for large mammal crossing sites and stream crossings.

Task 3a. Describe terrestrial wildlife road crossing mitigation measures appropriate for specific locations within Teton County.

- Develop a cost-benefit analysis to help evaluate the savings in reduced costs to society.
- Provide site-specific mitigation solutions for the five highest priority ungulate crossing sites. These must include high-level design recommendations, including some general visualizations in PDF or JPG format suitable for public presentation purposes. Provide schematic level cost opinions for each site-specific solution.
- Provide a strategy for monitoring of crossings and wildlife vehicle collisions to assess effectiveness of any proposed structures/measures.

Task 3b. Describe stream crossing measures appropriate for specific locations within Teton County.

Task 4. Describe potential sources of funding for wildlife crossing measures from federal, state, county, private groups and other sources.

Task 5. Hold one public meeting, midway through the development of the Master Plan process to hear public comment. Provide visual aids and present information at the public meeting on the proposed Master Plan

Task 6. Provide a final written Wildlife Crossings Master Plan document in a format ready for formal adoption by the Teton County Board of County Commissioners and attend the Board hearing to present the final master plan.

1.4. Suggestions on how to use the contents of this report

This reports compiles information on human safety and biological conservation for different highway sections in Teton County that was previously in different databases, publications or unpublished knowledge and experience. In addition, this report calculated the economic costs associated with large wild mammal-vehicle collisions along the highways in Teton county and the indicative costs associated with mitigation measures as this can help Teton County and other stakeholders with the decision process to implement effective mitigation measures aimed at reducing wildlife-vehicle collisions and providing safe crossing opportunities for wildlife. However, the outcome of the cost-benefit analyses should not be used as a litmus test for the potential implementation of mitigation measures as passive use values (e.g. the value of wildlife for wildlife viewing) are not part of the analyses.

This report also identifies and prioritizes highway sections that ranked highest based on a combination of human safety and economics, and biological conservation. This does not mean that mitigation along other highway sections is not warranted. It only means that, given the process described in this report, certain highway sections ranked higher than others. Furthermore, the report contains suggestions for implementing mitigation measures along the road sections that ranked highest. These suggestions are based on the objectives of reducing collisions with large wild mammals and providing safe crossing opportunities for wildlife, given the target species along a road section, and other local parameters such as traffic volume and local topography. The suggested mitigation measures should not be mistaken for actions that must happen exactly as described. Rather, the authors of this report suggest that the human safety, biological conservation, and economic information summarized in this report should be used to understand the why certain highway sections are important to mitigate, what species the mitigation measures should be targeted at, and what those mitigation measures could look like. However, the exact location, length or number, or type and dimensions of the mitigation measures is dependent on public support, agreements with private landowners and land management agencies, and the availability of funding.

2. LITERATURE REVIEW: TERRESTRIAL

2.1. A Step-Wise Approach

2.1.1. Step 1: Define the Problem

In North America wildlife mitigation measures along highways are often primarily based on a desire to improve safety for humans. While overall highway safety has improved substantially over the last several decades (Insurance Institute for Highway Safety, 2012), wildlife-vehicle collisions have increased by about 50 percent between 1990 and 2004 (Huijser et al., 2008). The total number of large mammal–vehicle collisions has been estimated at one to two million in the United States annually (Conover et al., 1995, Huijser et al., 2009). These collisions were estimated to cause 211 human fatalities, 29,000 human injuries, and over one billion US dollars in property damage annually (Conover et al., 1995). More recent estimates that include costs associated with human injuries and human fatalities estimate the yearly costs associated with wildlife-vehicle collisions between 6-12 billion US dollars (Huijser et al., 2009). The road sections that are selected for the implementation of wildlife mitigation measures are often primarily based on wildlife-vehicle collision data. Along most roads in North America there are two types of wildlife-vehicle collision data:

- Crash data: These data are typically collected by law enforcement personnel. For a crash to be entered into the database there is often a threshold (e.g. minimum estimated vehicle repair cost at least US $1,000) and/or human injuries and human fatalities (Huijser et al., 2007a).
- Carcass data: These data are typically collected by road maintenance crews when they remove carcasses of large mammals that are on the road or that are very visible from the road in the right-of-way and that are an immediate safety hazard or a distraction to drivers (Huijser et al., 2007a). Note that carcass data are sometimes also collected by personnel from natural resource management agencies, researchers, or the general public (e.g. Paul et al., 2013).

Both types of data tend to relate to large mammals only; medium sized and small sized mammals and other species groups such as amphibians, reptiles and birds are usually inconsistently recorded or not recorded at all (Huijser et al., 2007a). Furthermore, crash data typically represent only a fraction (14-50%) of the carcass data, even if both data sets relate to large mammals only (Tardif and Associates Inc,. 2003; Riley & Marcoux, 2006; Donaldson & Lafon, 2008). Finally, the carcass data are not complete either; animals that are not very visible from the road in the right-of-way may not be removed and do not get recorded. Wounded animals that make it beyond the right-of-way fence before they die are also usually not recorded at all.

If only wildlife-vehicle collision data (crash and carcass removal data) are used to identify and prioritize locations for wildlife mitigation measures, this biases decisions to deal only with human safety and reducing collisions with large mammals, specifically the most common ungulates such as mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*).

If the concern is with direct road mortality for species or species groups other than common large mammals, then data sources other than crash data and carcass removal data may be required. A specific road-kill monitoring program may have to be developed. Depending on the exact goals of the project and the associated requirements such data may be collected by personnel from natural resource management agencies, researchers or the public.

While there is much emphasis on mitigating for wildlife-vehicle collisions in North America, crashes, dead animals, and associated costs and risks to humans are not the only reason mitigation for wildlife along highways may be considered. The authors of this report distinguish five different categories of effects of roads and traffic on wildlife (Figure 2):

1. Loss of habitat: e.g., the paved road surface, heavily altered environment through the road bed with non-native substrate, and seeded species and mowing in the clear zone are all lost or dramatically altered habitat.
2. Road mortality: Direct wildlife road mortality as a result of collisions with vehicles.
3. Barrier to wildlife movements: e.g., animals do not cross the road as often as they would have crossed natural terrain and only a portion of the crossing attempts is successful.
4. Decrease in habitat quality in a zone adjacent to the road: e.g., noise and light disturbance, air and water pollution, increased human presence in the areas adjacent to the highways.
5. Ecological function of verges: Depending on the surrounding landscape, the right-of-way (verge) can promote the spread of non-native or invasive species (in a surrounding landscape largely natural or semi-natural) or it can be a refugium for native species (surrounding landscape heavily impacted by humans).

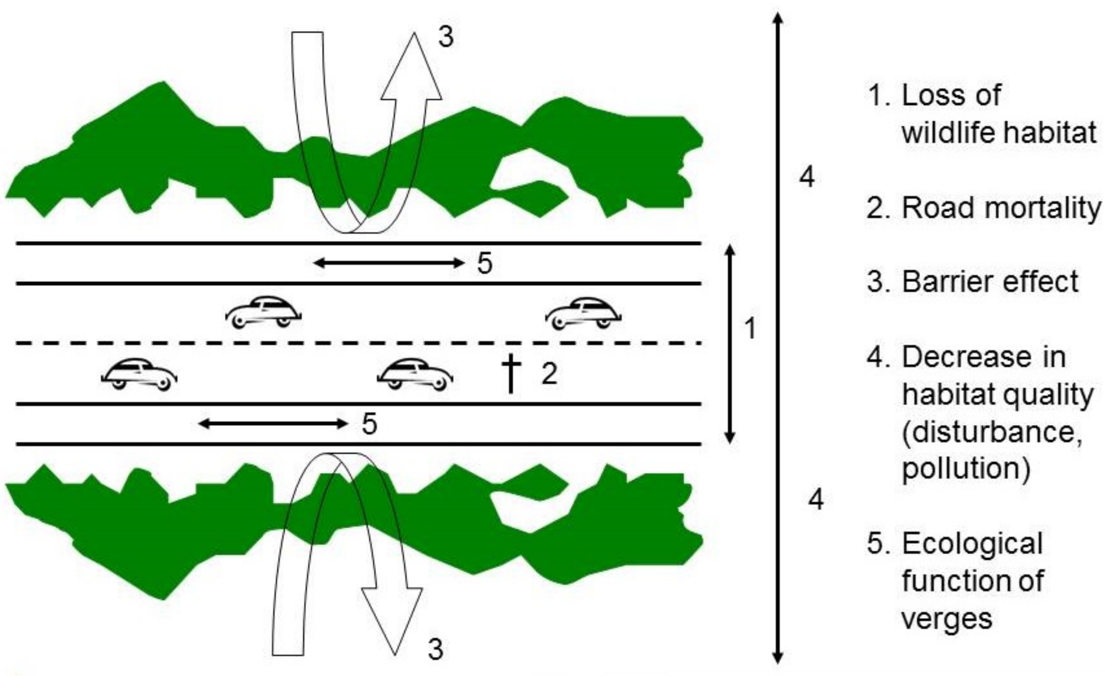


Figure 2: The effects of roads and traffic on wildlife.

If mitigation is required for habitat loss, barrier effects, a decrease in habitat quality in a zone adjacent to the road, or the ecological functioning of right-of-ways, other types of data are needed than wildlife-vehicle collision data. Examples of such data are data on the quantity and quality of the habitat impacted, animal movement data, data on noise or chemical pollutants, and the presence of non-native invasive species. Note that wildlife-vehicle collision hotspots are not necessarily the locations where animals cross the road most frequently or where safe crossing opportunities would have the greatest benefit to the long-term population viability for selected species.

2.1.2. Step 2: Decide on the Approach: Avoidance, Mitigation, or Compensation

While mitigation (reducing the severity of an impact) is common, avoidance is better and should generally be considered first (Cuperus et al., 1999). For example, the negative effects of roads and traffic may be avoided if a road is not constructed, or the most severe negative effects may be avoided by re-routing away from the most sensitive areas (Figure 3). If the effects cannot be avoided, mitigation is a logical second step. Mitigation is typically done in the road-effect zone (Figure 2) and may include measures aimed at reducing wildlife-vehicle collisions and reducing the barrier effect (e.g., through providing for safe wildlife crossing opportunities) (Huijser et al., 2008; Clevenger & Huijser, 2011). However, mitigation may not always be possible, or the mitigation may not be sufficient. Then a third approach may be considered: compensation or mitigation off-site. Compensation may include increasing the size of existing habitat patches, creating new habitat patches or improving the connectivity between the habitat patches that would allow for larger, more connected, and more viable network populations. Finally, in some situations a combination of avoidance, mitigation, and compensation may be implemented.

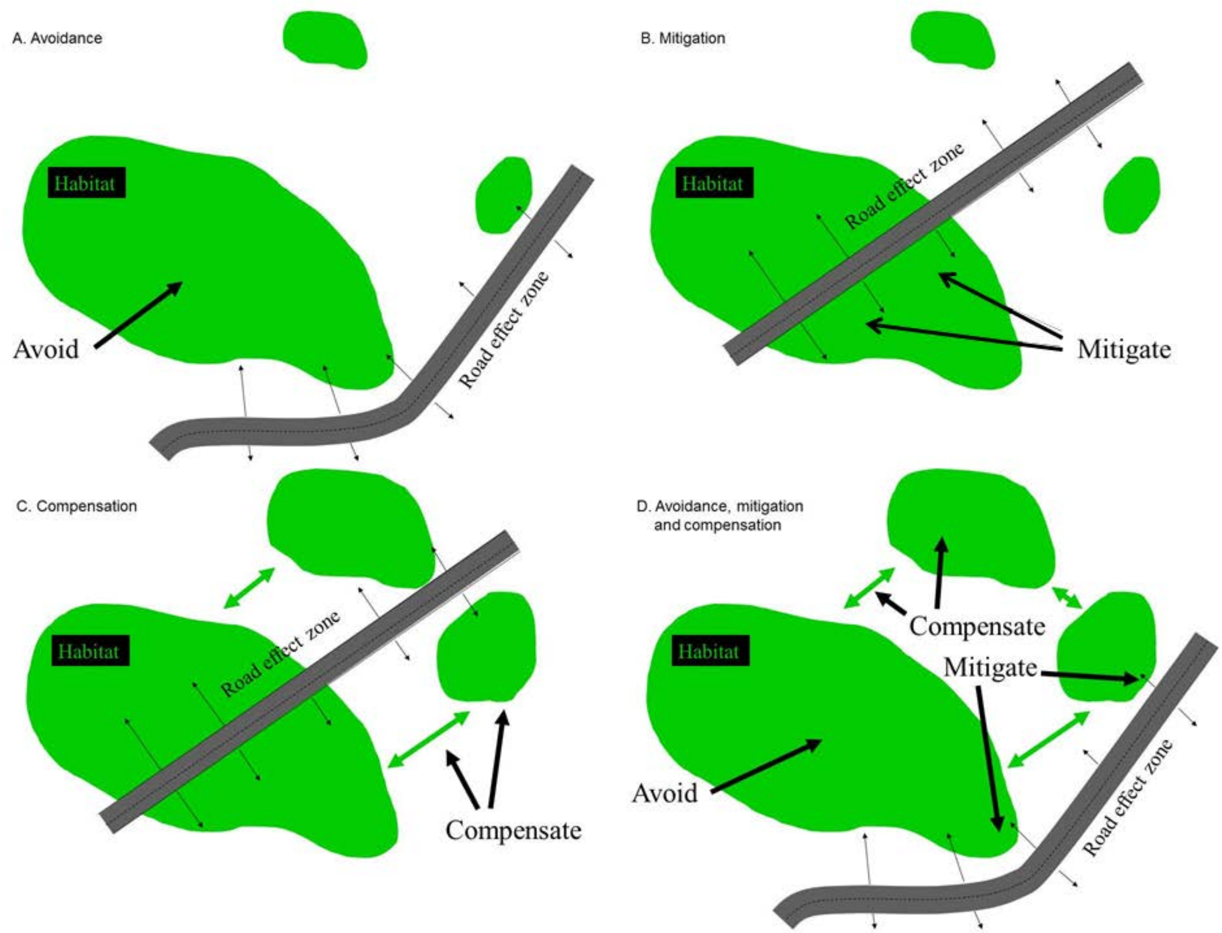


Figure 3: A three step approach: A. Avoidance, B. Mitigation, C. Compensation, D. Combination of avoidance, mitigation and compensation.

2.2. Teton County and Highway Mitigation for Large Mammals

Teton County is in the Greater Yellowstone Ecosystem, a uniquely intact ecosystem that is home to abundant and diverse wildlife species. At the same time, Teton County's human population and number of commuters is growing rapidly, at times coming into conflict with wildlife. One consequence of these developments is rising traffic volume and an associated increase in the ecological impacts of roads. Vehicle collisions with large mammals also pose a significant human safety problem.

Protecting wildlife populations is a central community value, as reflected in the Teton County Comprehensive Plan. At present, however, there is no comprehensive plan for how to achieve this goal in Teton County. A Wildlife Crossings Master Plan would set priorities, identify suitable mitigation measures, and provide cost estimates for effective and safe wildlife crossings in the County.

The Wildlife Crossings Master Plan for Teton County aims to improve human safety through a reduction in collisions with large mammals and providing safe crossing opportunities for wildlife. Large mammal species that are most frequently involved with wildlife-vehicle collisions in Teton County include deer (*Odocoileus* spp.), elk (*Cervus canadensis*) and moose (*Alces americanus*) (Huijser et al., 2011). Large mammal species that are of specific conservation concern in Teton County include moose, gray wolf (*Canis lupus*), wolverine (*Gulo gulo*), and bighorn sheep (*Ovis canadensi*s) (Pers. Communication Susan Johnson, Teton County Planning Department, based upon May 2016 list developed for the Focal Species Habitat Mapping Project). Other medium and large wild mammal species in the region that are, or -until recently -, were a concern to conservation on a state, national or international level -recognized by government agencies or not - include northern river otter (Lontra canadensis) Canada lynx (*Lynx canadensis*), grizzly bear (*Ursus arctos*), and bison (*Bison bison*) (IUCN, 2017; Wyoming Game & Fish Department, 2017)). In addition, Teton County and surrounding areas host some of the longest ungulate migrations in North America. Specifically, pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), bighorn sheep (*Ovis canadensis*), and moose (*Alces americanus*) are known to move or have moved considerable distances between summer and winter habitat (e.g. Riginos et al., 2013; Sawyer et al., 2016; Aikens et al., 2017; Courtemanch et al., 2017; Wyoming Migration Initiative, 2017). Land use and artificial barriers on the landscape such as, transportation corridors, and reservoirs, can affect these migrations.

The Wildlife Crossings Master Plan for Teton County needs to take the species into account that have been identified as a conservation concern. This means that the plan should address road sections that have a known concentration of collisions with these species and road sections that bisect important habitat or migration corridors. The goal is to both improve human safety, and habitat connectivity for wildlife.

It is unlikely that the existing highways in Teton County will be removed or rerouted to avoid the most severe impacts on wildlife. Therefore, the measures included in the Wildlife Crossings Master Plan are focused on reducing or “mitigating” the impacts. Compensation measures require agreements with (other) land owners and are not part of this report.

2.3. Traffic Volumes and Speed limits on Highways Teton County

Most of the highway sections in Teton County have an average daily traffic volume of about 10,000 vehicles, but WY 22 between Jackson and the junction with WY 390 is the busiest with about 19,000 vehicles per day (Figure 4). However, Teton County is a popular summer and winter destination for tourists, which means that the maximum daily traffic volume for the busiest road sections around Jackson is between 13,000 and 23,000 vehicles. WY 390 (section 7) is less busy, but still has an average of 7,000 vehicles per day. WY 22 on the Teton Pass and west of Teton Pass, and section 2 (west of Hoback Jct) receive about 5,000 vehicles per day. Section 1 (east of Hoback Jct) and section 5 (Togwotee Pass) are the least traveled road sections with an average of about 1,500 vehicles per day.

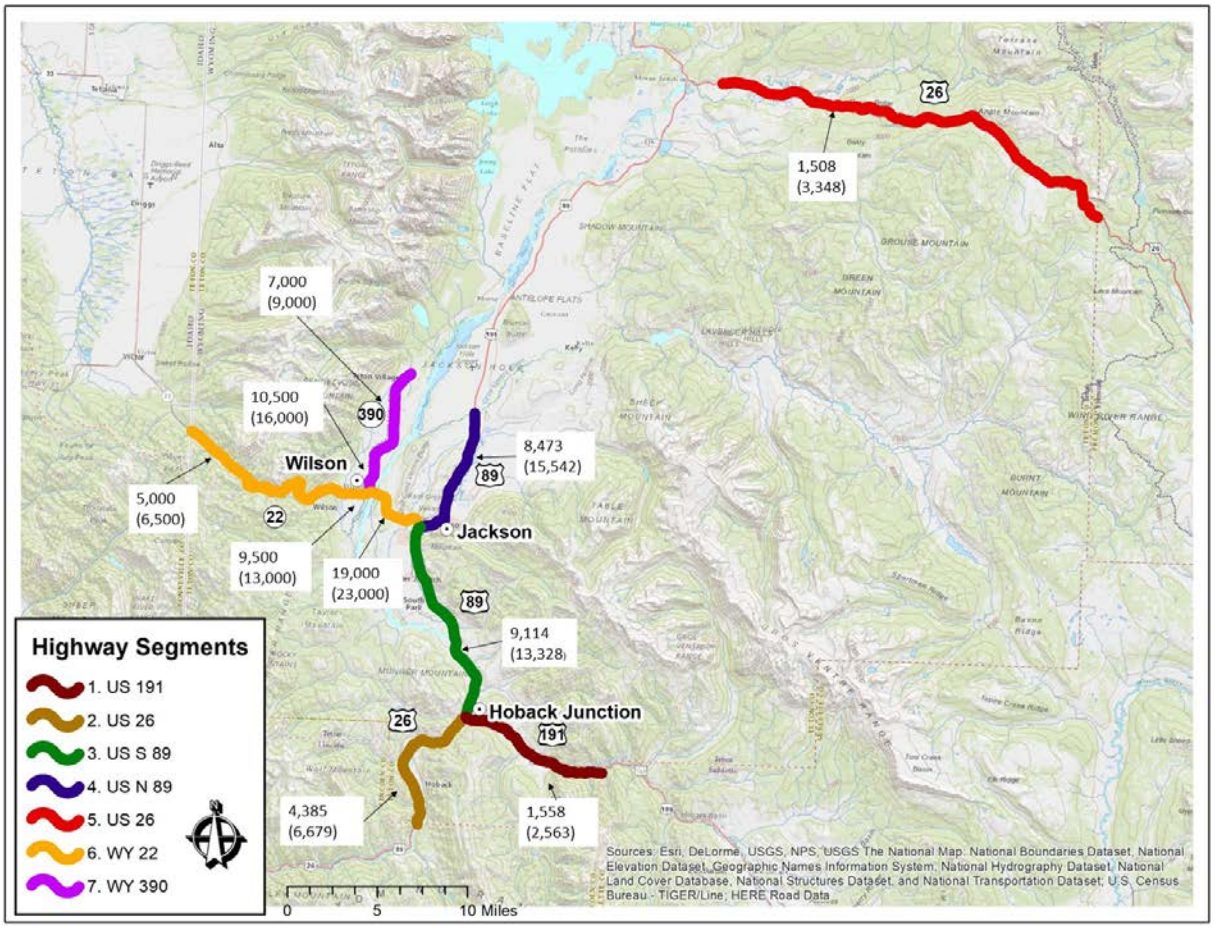


Figure 4: Average Annual Daily Traffic (AADT) and maximum daily traffic volume (between brackets) for road sections 1, 2, 3, 4, and 5, and Average Daily Traffic in the summer and maximum daily traffic volume (between brackets) in summer for road sections 6 and 7 on the Highways in Teton County (Jacobs, 2014; WYDOT, 2017).

Most of the highways in Teton County have a posted speed limit of 55 or 65 mi/h (Figure 5). Some road sections in Jackson and the junction between WY 22 and WY 390 have lower speed limits (35-40 mi/h). Section 4, north of Jackson has reduced night and daytime speed limit (45 mi/h) approaching the boundary with Grand Teton National Park. WY 390 Has a speed limit of 45 mi/h, but the first few miles from the Jct with WY 22 also have a reduced night time speed limit of 35 mi/h. The latter was implemented because of a concern for moose-vehicle collisions.

Many of the road sections have wildlife warning signs. WY 390 also has a variable message sign to alert driver for moose, and some property owners have placed moose silhouette signs on the right-of-way boundary.

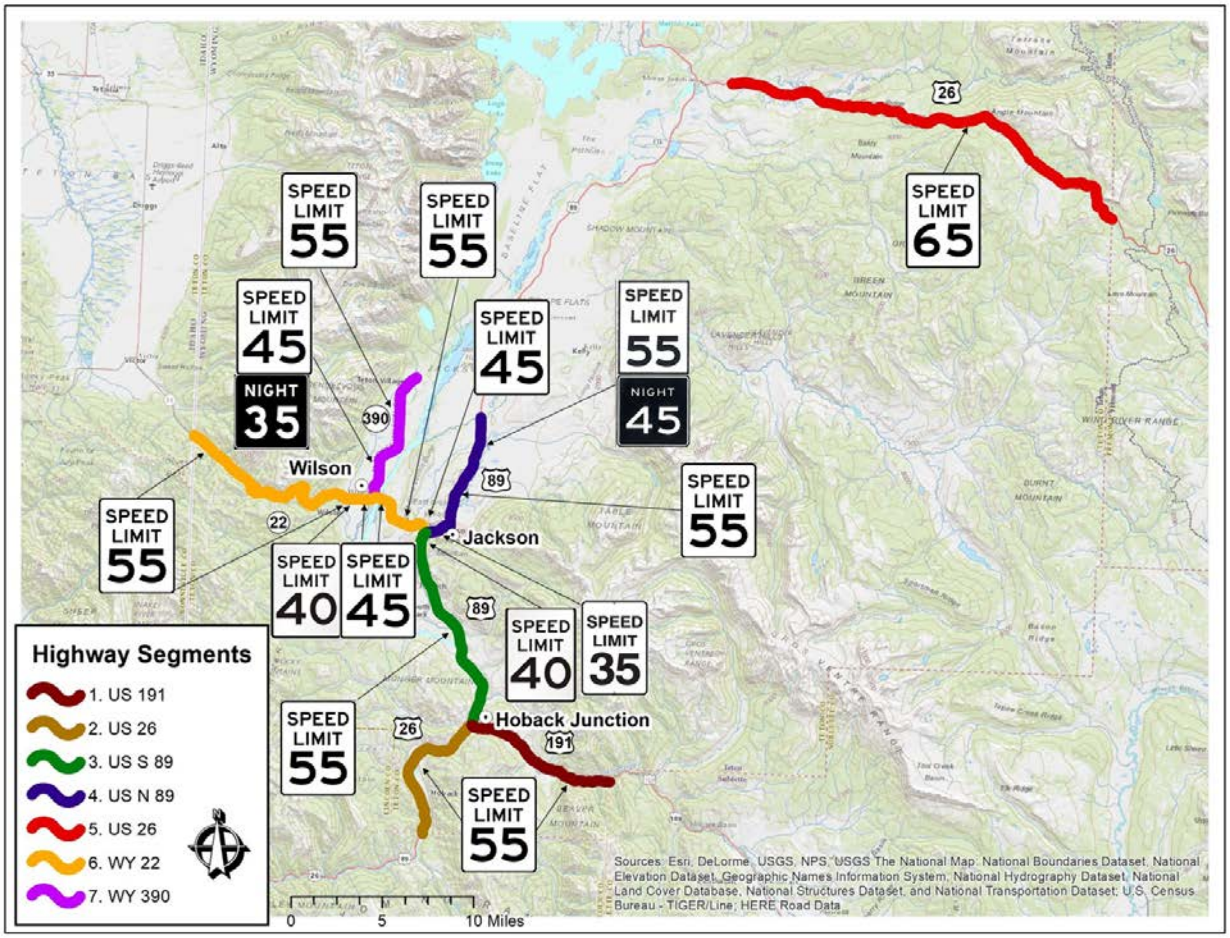


Figure 5: Posted maximum speed limits along the highways in Teton County. Note: WY 22 east of Wilson until the Jct with US Hwy 26/89/191 has a reduced speed limit of 45 mi/h in winter.

2.4. Mitigation Measures

2.4.1. Selection of Mitigation Measures

The researchers selected mitigation measures that are known to substantially reduce wildlife-vehicle collisions with large mammals and that also provide safe crossing opportunities for wildlife. While about 40 different types and combinations of mitigation measures have been implemented or described, not all have them have been thoroughly evaluated for their effectiveness (Evink 2002; Iuell et al., 2003; Foreman et al., 2003, Huijser et al., 2007b; Huijser et al., 2008; Knapp et al., 2004). However, wildlife fences in combination with wildlife crossing structures (i.e. overpasses and underpass) have been identified as the most effective and robust mitigation measures that address both the human safety and the biological conservation concerns and that can often be justified based on human safety-based economics alone (Huijser et al., 2008; Huijser et al., 2009; Clevenger & Huijser, 2011; Rytwinski, et al., 2016). Animal detection systems can be similarly effective in reducing wildlife-vehicle collisions (Huijser et al., 2015a). Therefore, our review will focus on wildlife fences in combination with wildlife crossing structures, and animal detection systems. However, because standard and enhanced wildlife warning signs not associated with an animal detection system and speed limit reduction are often requested and implemented, we also include a brief review on their effectiveness.

2.4.2. Wildlife Warning Signs and Animal Detection Systems

One of the most commonly applied measures to attempt to reduce wildlife-vehicle collisions is to install wildlife warning signs. The abundance of wildlife warning signs is probably related to engrained practices and perceived low costs of the signs. Unfortunately, most studies indicate that standard and enhanced wildlife warning signs do not reduce wildlife-vehicle collisions (Huijser et al., 2015a; Riginos et al., 2016). Standard wildlife warning signs have black animal symbols on a yellow background. Enhanced wildlife warning signs include large signs, signs with flags or permanently flashing amber lights, signs with unusual text or symbols designed to attract the attention of the driver and inform them about the impact of wildlife-vehicle collisions in the area, and variable message signs. Wildlife warning signs that are specific in time and place can result in some reduction ((9-50% reduction for temporary wildlife warning signs for migratory species) or a more substantial reduction (33-97% reduction for animal detection systems) in wildlife-vehicle collisions (Huijser et al., 2015a). If the objective is to reduce wildlife-vehicle collisions, then standard or enhanced wildlife warning signs are not an effective tool. Standard or enhanced wildlife warning signs may still have a function in providing legal protection to transportation organizations in case of a collision, in providing information to the public, in increasing general awareness of the problem, and in potentially increasing public support for other mitigation measures that are effective in reducing wildlife-vehicle collisions (Huijser et al., 2015a).

For animal detection systems to be effective, the warning signs have to be reliable (Figure 6). Drivers can then respond through being more alert, through a reduction in vehicle speed, or both (Figure 6).

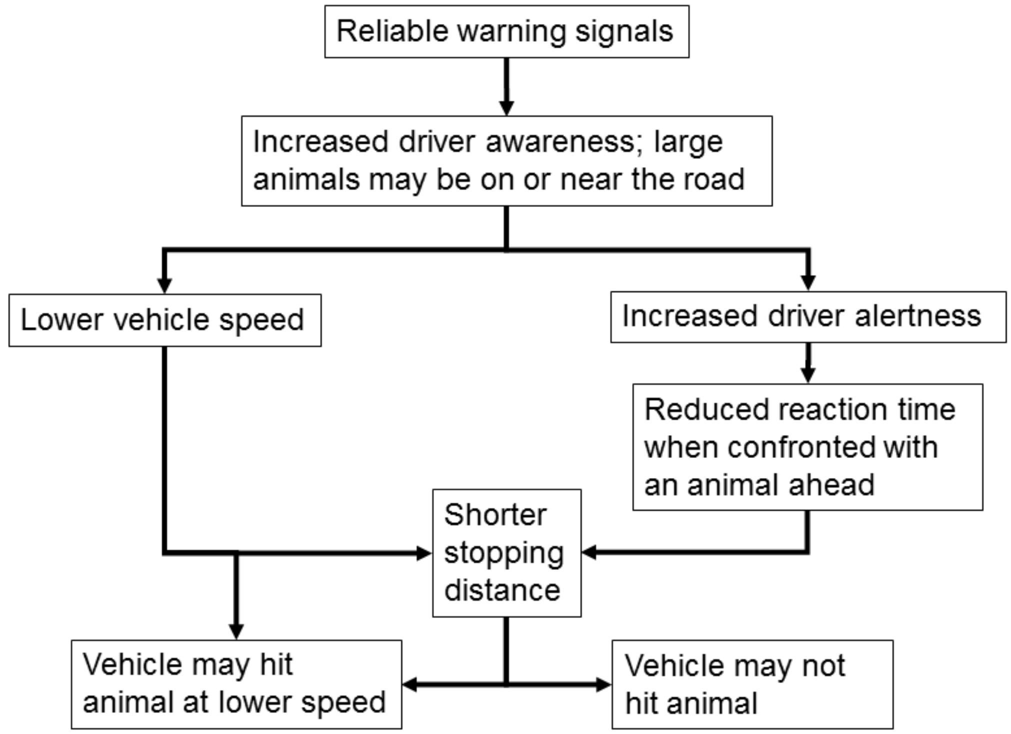


Figure 6: Warning signs must be reliable before they can be effective (reproduced from Huijser et al. 2006).

Suggestions and considerations:

1. If the objective is to reduce wildlife-vehicle collisions, then recognize that standard or enhanced wildlife warning signs are not an effective mitigation measure.
2. Warning signs that are more specific in time and place can reduce wildlife-vehicle collisions somewhat: 9–50% reduction for seasonal warning signs for migratory ungulates (Sullivan et al., 2004; CDOT, 2012), and 33–97% for animal detection systems (review in Huijser et al., 2015a)
3. If animal detection systems are implemented on their own (i.e. without wildlife fences), they do not restrict where animals can cross the highway.
4. Animal detection systems come with a range of limitations: They do not physically separate wildlife from traffic and thus still allow for the potential for collisions, they are mostly used on low volume roads (e.g. <5,000 vehicles per day) to limit the likelihood or rear-end collisions when vehicles brake suddenly, vehicle speed may have to be reduced substantially (e.g. 35-40 miles per hour aided by mandatory speed limit reduction) to substantially reduce the likelihood of a collision (Huijser et al., 2015a; in prep.), and the design (reliability), implementation and maintenance of these systems is typically very challenging. Therefore, learn about the limitations and risks associated with animal detection systems before initiating their implementation (Huijser et al., 2015a).

2.4.3. Speed Management

Speed management is often suggested as a strategy to reduce wildlife-vehicle collisions. However, speed management is complex and it is important to distinguish between three types of “speed”:

1. The design speed of a highway. This is used by engineers who then design the associated road characteristics such as lane and shoulder width, curvature, access density, and sight distance. These characteristics physically allow drivers to drive a certain speed in a safe and responsible manner.
2. The posted speed limit. This is the legal speed limit depicted on signs. This is typically a the 85th percentile of the vehicle speeds and should not exceed the design speed of a road.
3. The operating speed of the vehicles. This is the speed that drivers actually drive.

Most wildlife-vehicle collisions happen between dusk and dawn when visibility is limited (Huijser et al., 2008). However, the design speed, posted speed limit and operating speed of major highways is typically too high and the head lights of vehicles do not shine far enough to detect large mammals early enough to allow drivers to stop their vehicle in time (Huijser et al., 2017) (Figure 7). With median headlights (low beam) and a 1.5 second reaction time, drivers can, at a maximum, drive 40 mi/h and still avoid a collision (Figure 7). Higher vehicle speeds do not allow drivers with median headlights to avoid a collision with a large mammal on the highway. Since half the cars have headlights that have a shorter reach, an operating speed of 40 mi/h would still not allow half the drivers to stop their vehicle in time. To allow (almost) all drivers to stop their vehicle in time, operating speed may need to be as low as 25-30 mi/h (Figure 7). This is far lower than the design speed of most roads.

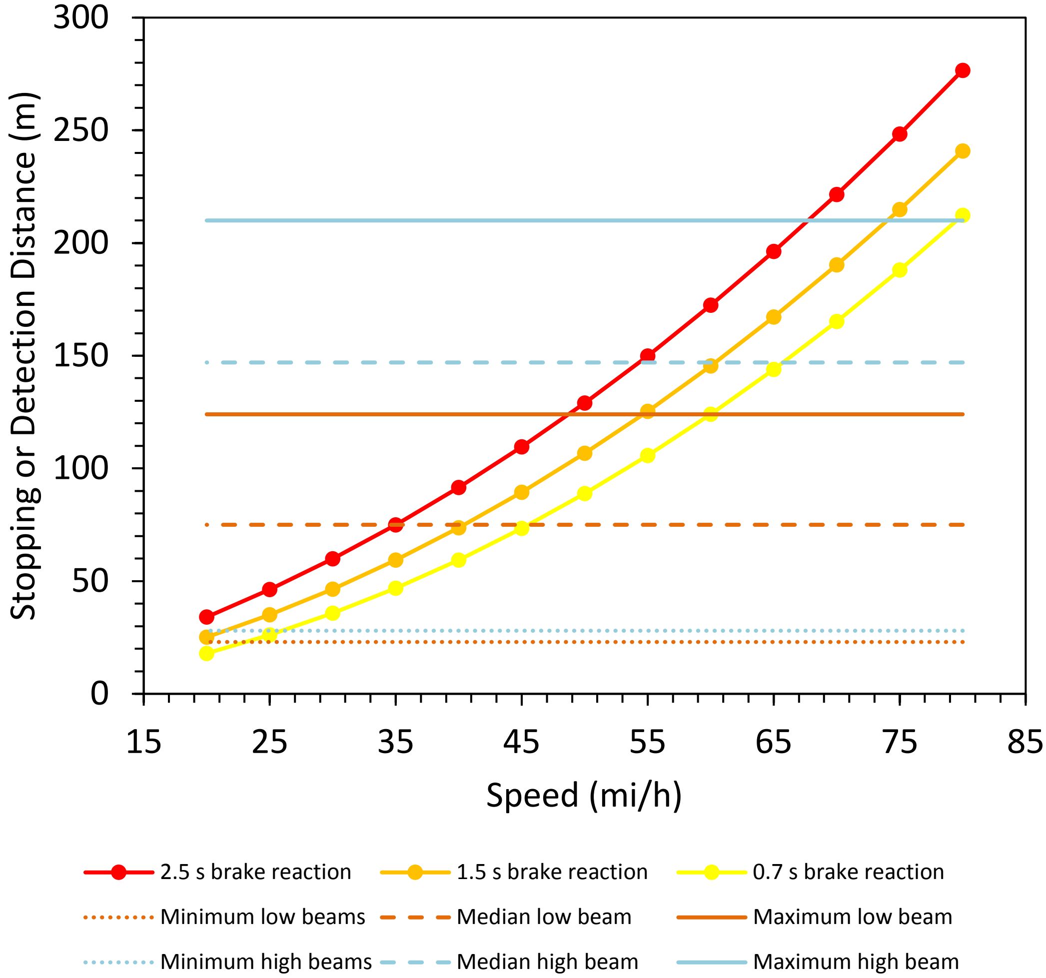


Figure 7. Stopping Distances and Detection Distances for Large Mammals (For more details on methods see Huijser et al., 2017)

Most drivers drive a speed (operating speed) that is close to or higher than the design speed of a rural road (Fitzpatrick et al., 2003; Jiang et al., 2016; Donnell et al., 2018). If the posted speed limit is substantially reduced below the design speed for a rural road section through a sensitive area, and if the design speed remains the same for this road section, the following scenario is likely:

1. Most drivers will ignore the lower posted speed limit and continue to drive a speed close to or higher than the design speed of the highway.
2. Some drivers will adhere to the lowered posted speed limit.
3. The mix of fast and slow-moving vehicles on a highway is referred to as "speed dispersion" and this is associated with more interaction between vehicles, dangerous driving behavior (e.g. irresponsible maneuvers to overtake slow vehicles) and an overall increase in crashes (Bing et al., 2013; Elvik, 2014).

For these reasons alone, it is never a good idea to implement a posted speed limit that is substantially lower than the design speed of a highway. Transportation agencies typically respond to drivers who ignore the posted speed limit and who drive a speed that is close to the design speed of a road by increasing enforcement of the lowered posted speed limit (e.g. through radar measurements of vehicle speed and fining the speeders). If the radar posts are at fixed locations, drivers who travel the road section regularly will quickly learn about the location of the radar posts and lower the speed of their vehicle only in the immediate vicinity of the radar posts. This leads to further speed variation and associated risks, additional use of fuel through braking and acceleration, and the road sections in between the radar posts do not actually have slower moving traffic. Finally, drivers that do get "caught" are likely to experience the situation as "unjust". One cannot reasonably be expected to drive "slow" on a highway that has "wide" lanes, "wide" shoulders, "gentle" curvature and "long" sight distances. This is likely to eventually result in pressure to make the posted speed limit more consistent with the design speed of the road.

Suggestions and considerations:

1. It is not an effective or wise mitigation strategy to implement a posted speed limit that is substantially lower than the design speed of a highway.
2. Only consider lowering the posted speed limit if the design speed is reduced accordingly. Depending on the purpose of a highway, lowering the design speed and lowering the posted speed limit may be in direct conflict with the need for "efficient" transportation and this may therefore not be a viable strategy for most highways.
3. For speed management to be substantially effective as a measure to reduce collisions with large mammals for more than half the drivers, the design speed, mandatory speed limit, and actual operating speed of the vehicles may need to be 35-40 miles per hour at a maximum (Huijser et al., 2015a; Huijser et al., 2017).
4. In summary, we recommend that reduced speed limits only be considered for the portions of the study area that already have low design speed or that have substantial residential and commercial development and associated access roads (e.g. WY 390, US Hwy 89/189/191 as it passes through Jackson town), but not on other highways where the design speed is high and the risk of speed dispersion makes it unsafe to substantially lower the posted speed limit.

2.4.4. Wildlife Fences

Wildlife fences prevent animals from entering the road, and they are one of the most effective and robust mitigation measures to reduce collisions with large mammals (Clevenger et al., 2001; Huijser et al., 2009; Huijser et al., 2015b; Rytwinski, et al., 2016). However, fences alone also increase the barrier effect of roads and traffic and may result in a near absolute barrier for wildlife in the landscape. Small and fragmented wildlife populations have reduced population survival probability (Jaeger & Fahrig, 2004). Wildlife fencing reduces or eliminates daily movements within an animal's home range and hinders seasonal migration and dispersal movements. These different movement types are vital to the overall population viability of a species in a region. Therefore, we only recommend wildlife fencing when it is combined with safe crossing opportunities. If combined with safe crossing opportunities, wildlife fencing not only reduces wildlife-vehicle collisions but also guides the animals towards these safe crossing opportunities (Dodd et al., 2007; Gagnon et al., 2010). In addition, if sufficient and appropriate safe crossing opportunities are provided, individual animals are less likely to breach the fence and enter the fenced road corridor. Wildlife crossing opportunities in combination with fencing can be divided into at-grade crossings, where the animals cross on the road surface, and separated crossings (underpasses and overpasses) where animals cross under or over the road surface. Wildlife underpasses and overpasses provide the most robust, safe crossing opportunities (Clevenger & Huijser, 2011) while animal detection systems or other at grade crossing opportunities should be considered more experimental (Huijser et al., 2009a; Huijser et al., 2015a).

Thus, the purpose of wildlife fencing is to:

1. Keep wildlife off the highway and, therefore, reduce wildlife-vehicle collisions.
2. Funnel wildlife movements to safe crossing opportunities (e.g. wildlife underpasses or overpasses).

To keep wildlife off the highway, it is essential to define the target species before designing wildlife fencing. The climbing, jumping, and digging capabilities of the target species as well as their strength (e.g. ability to push or ram through fencing) needs to be considered (Huijser et al., 2015b). These species characteristics influence fence height, the type of fencing material (e.g. mesh-wire, chain-link, electric), the type of post (wood, metal, concrete), the strength of the material, as well as specific features to discourage climbing (e.g. outriggers) or digging (dig barrier) (Huijser et al., 2015b). Given the target species within Teton County, the wildlife fence needs to be sufficiently tall for large ungulates, and it needs to have dig barriers for gray wolf and wolverine if the fences are to reduce road mortality for these species too and helpguide them towards safe crossing opportunities. This would then result in a woven wire fence (8 ft tall), wooden posts, and a buried apron (Huijser et al., 2015b). Should black bears (*Ursus americanus*) or other species that have good climbing skills also be a concern, then the wooden posts should be replaced with metal posts, the wire mesh fencing should be replaced with chain-link fencing, and a fence overhang should be provided. Should mountain lion (*Puma concolor*) also be a concern, the height of the fence should be increased from 8 to 12 ft (Huijser et al., 2015b). During the installation of wildlife fencing care should be taken not to leave gaps between the ground and the bottom of the fence, and, dependent on the target species and their climbing capabilities, a wildlife fence should typically maintain a certain minimum distance from trees and shrubs, including overhanging branches. Fence maintenance can be a problem, but without proper maintenance, wildlife fences become ineffective in keeping animals off the highway and directing them to safe crossing opportunities.

In multifunctional landscapes such as Teton County, there is a tendency to construct wildlife crossing structures with limited fences or no fences at all (Huijser et al., 2016a). However, a recent meta-analysis showed that short fenced road sections (<3 mi road length) are less effective in reducing collisions with large ungulates (50% on average) than longer sections (>3 mi road length; typically 80-100%) (Huijser et al., 2016a). Fence-end treatments and other measures that encourage wildlife to cross the road straight at fence ends and that discourage them from wandering into the fenced road corridor are essential, especially for relatively short mitigated road sections. This new knowledge is especially relevant in multi-functional landscapes such as Teton County with varied land use, where landscape aesthetics are a concern. Possible solutions include fence-end treatments (i.e. electric mats or electric concrete embedded in the pavement at fence ends). However, while such fence end treatments can increase the effectiveness of the mitigated road section, short sections of wildlife fences may still cause a spatial shift in wildlife-vehicle collisions rather than a substantial reduction along the entire corridor. More robust approaches include long sections of wildlife fences. When landscape aesthetics are a concern, the visibility of the wildlife fences from the highway may be reduced (e.g. green or dark color of the fence; careful placement of fence in relation to topography or vegetation), and selective use of retaining walls that are integrated in the road bed. The latter may include raising the road bed or lowering the areas immediately adjacent to the roadbed.

Escape ramps or jump-outs are designed to allow medium and large mammals to safely exit fenced right-of-ways on their own. Jump-outs should be low enough to encourage animals to jump to the safe side of the fence, and they should be high enough so that animals are discouraged from jumping into the fenced road corridor. Other measures that allow animals to escape from the fenced road corridor include one-way gates, tree trunks or branches stacked against the fence, and gates that are opened by wildlife managers who then haze the animals towards the open gate and the safe side of the fence. For deer, a height of 6-6.5 ft may be optimal (Huijser et al., 2015b). Note that adding a bar on top of the jump-out can further reduce the likelihood of animals jumping into the fenced road corridor (Huijser et al., 2015b). While there is no standard for the placement and distance between jump-outs, they have been implemented at about 1000 ft. The best locations for jump-outs may be at crossing structures, and at locations where the fence is at greater distance from the pavement, and where human disturbance from the road corridor is reduced by the topography or vegetation (Huijser et al., 2015).

Suggestions and considerations:

1. Do not implement wildlife fencing without also providing for safe crossing opportunities for wildlife.
2. Before designing a wildlife fence, decide on the “target species”.
3. Base the design of wildlife fence on the biological characteristics of the target species.
4. Use material (fence posts, fencing material) that is consistent with the desired lifespan of the fence.
5. Oversee fence installation to make sure no gaps or other weak points in the fence result.
6. Implement fence maintenance programs, including for fallen trees and vegetation growing on and over fences. Without fence maintenance, wildlife fences typically become dysfunctional quickly.
7. When implementing wildlife fencing (in combination with safe crossing opportunities for wildlife) consider implementing the fencing over at least 3 miles of road length rather than at shorter road sections.
8. At wildlife crossing opportunities, make the wildlife fencing connect to the wildlife crossing structures without gaps in between.
9. Standard right-of-way fencing, or livestock fencing, is best avoided at the approaches to wildlife crossing structures. If a right-of-way fence or livestock fence must be present at the approaches of safe crossing opportunities, install a wildlife friendly design (e.g. Paige, 2012). It is best to have a smooth top and bottom wire (no barbed wire) so that wildlife can more easily jump the fence or crawl under the fence without injuring themselves. Alternatively, top and bottom wires can be run through PVC tubing, and the top two wires or the bottom two wires (assuming there are 4 strands in total) can be

combined in PVC tubing, effectively lowering the fence height, and creating more space between the ground and the first wire(s).

10. Wildlife fencing should cover the road length that may have a concentration of wildlife-vehicle collisions with the target species (i.e. "hotspots") and adjacent buffer zones to keep the animals from simply crossing the highway at the fence ends. The home range size of the target species and the habitat adjacent to the highway should at least partially influence the length of the buffer zone.
11. Always install wildlife fencing on both sides of a highway, not only on one side.
12. Always try to have wildlife fencing start and end on opposite sides of the highway rather than in a staggered pattern.
13. Consider implementing wildlife guards (similar to cattle guards) or electric mats embedded in the roadway to reduce wildlife intrusions into the fenced road corridor at fence ends and at access roads. Wildlife guards made from modified bridge grate material are a substantial barrier to ungulates, but not to gray wolf, wolverine, black bear, grizzly bear, or mountain lion (Allen et al., 2013; Huijser et al., 2015b). Consider electric mats or concrete when non-ungulates are among the target species.
14. Fence end treatments (e.g. wildlife guard or electric mat embedded in the pavement) are especially important if the mitigated road length is relatively short in relation to the mortality hotspot and suggested buffer zones. While fence end treatments are likely to reduce intrusions by wildlife into the fenced road corridor, they do not address potential "fence end runs" by wildlife and the problem of moving rather than reducing wildlife-vehicle collisions.
15. Include wildlife jump-outs or escape ramps (e.g. every 1000 ft, especially at wildlife crossing structures and areas that are less visible from the highway).
16. Minimize the number of access roads in the fenced road sections (access roads to the mitigated road require a fence gap). Mitigate access roads and associated fence gaps through wildlife guards (effective barrier to ungulates) or electric mats or concrete (Huijser et al., 2015b).
17. In areas where landscape aesthetics (e.g. view of the mountains from the highway) are a concern, consider the use barrier walls embedded in the roadbed, or place fencing further from the highway.

2.4.5. Wildlife Crossing Opportunities

The purpose of wildlife crossing structures is to:

1. Allow wildlife to safely cross to the other side of the highway.
2. Reduce intrusions by wildlife into the fenced road corridor by providing more convenient and safe crossing opportunities.

Similar to wildlife fencing, the number, location, type (e.g. at-grade, overpass or underpass), and dimensions of safe wildlife crossing opportunities are at least partially influenced by the characteristics of the target species. Different species use certain types and dimensions of crossing opportunities more readily. At grade crossing opportunities (e.g. a gap in a wildlife fence on both sides of the highway) should probably only be considered at low volume roads (e.g. < 5,000 vehicles per day), potentially in combination with an animal detection system and electric mats or concrete embedded in the pavement to keep wildlife from entering the fenced road corridor (Huijser et al., 2015a; b). However, note that animal detection systems should still be considered experimental and that many projects fail because of technical and management issues. Higher volume highways (certainly above 15,000 vehicles per day, but the recommended threshold may be somewhere between 5,000 and 15,000 vehicles per day) typically require a physical separation of traffic and wildlife through the construction of wildlife underpasses or overpasses.

The tables below provide a classification for the types and dimensions of wildlife crossing structures (i.e. underpasses and overpasses) (Table 1), and an indication of which types and dimensions are considered appropriate for selected medium and large mammal species known to occur in Teton County (Table 2).

Table 1. Dimensions of the safe crossing opportunities recommended for implementation on or along the roads in the study area.

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

Table 2. Suitability of different types of mitigation measures for selected species. ● Recommended/Optimum solution; ⭘ Possible if adapted to local conditions; ⊗ Not recommended; ? Unknown, more data are required; — Not applicable (Clevenger & Huijser, 2011; Clevenger, unpublished data; Sawyer et al., 2016).

	Wildlife overpass	Open span bridge	Large mammal underpass	Medium mammal underpass	Small-medium mammal pipes	Animal detection system (experimental)
Ungulates						
Pronghorn	●	?	⊗	⊗	⊗	●
Deer sp.	●	●	●	⊗	⊗	●
Elk	●	●	⭘	⊗	⊗	●
Moose	●	●	⭘	⊗	⊗	●
Bison	●	●	?	⊗	⊗	●
Bighorn sheep	●	●	⭘	⊗	⊗	●
Carnivores						
Wolverine	●	?	?	?	⊗	⊗
Bobcat	●	●	●	●	⊗	⊗
Canada lynx	●	?	?	?	⊗	⊗
Mountain lion	●	●	●	⊗	⊗	⭘
Coyote	●	●	●	●	⊗	⊗
Gray wolf	●	●	⭘	⊗	⊗	⭘
Black bear	●	●	●	⊗	⊗	●
Grizzly bear	●	⭘	⭘	⊗	⊗	●

It is best to construct wildlife crossing structures in such a way that they allow wildlife that approach the road to see the sky and vegetation on the other side of the road through or across the structure. This means that the approach for wildlife should preferably be level (try to avoid steep slopes at the approaches, perhaps 10-15 degrees at a maximum), and that two separate structures for the two travel directions for highways with a median should be designed as one wildlife crossing structure with a good line of sight to the other side of the transportation corridor.

Suggestions and recommendations:

1. Locate safe crossing opportunities for wildlife in road sections where connectivity for wildlife is needed most. Note that this is not always the same road section where wildlife is hit most often as the location of wildlife-vehicle collisions do not necessarily reflect where wildlife cross the road most often (unsuccessful and successful crossing combined) or where connectivity is needed but where the barrier effect of the transportation corridor keeps the animals from trying to cross the road.

2. Wildlife crossing opportunities without (functional) wildlife fencing are likely to have fewer wildlife move through the structure (Dodd et al., 2007; Gagnon et al., 2010).
3. Wildlife crossing structures without (functional) wildlife fencing are unlikely to substantially reduce wildlife-vehicle collisions (Huijser et al., 2015; Rytwinsky et al., 2016). The primary measure to reduce wildlife-vehicle collisions is wildlife fencing, not wildlife crossing structures.
4. Before designing safe wildlife crossing opportunities, and before deciding on the number and location of the safe crossing opportunities, decide on the “target species”.
5. Build a greater variety of types of wildlife crossing structures; not only wildlife underpasses, but also vegetated wildlife overpasses, especially if wildlife overpasses are clearly used most frequently by a target species (e.g. moose, grizzly bear, pronghorn, elk). Of course, it is important to do this with the biology of the target species in mind and at locations where it makes most sense based on topography and soil stability.
6. Build a greater variety of dimensions for wildlife underpasses (e.g. include larger underpasses (e.g. about 7-10 m wide, 3-5 m high) and smaller pipes (e.g. 0.5-1.0 m in diameter). Of course, it is important to do this with the biology of the target species in mind and at locations where it makes most sense.
7. When the dimensions allow, provide cover (e.g. tree trunks and branches) inside underpasses or on top of overpasses to encourage invertebrates, amphibians, reptiles, and small mammals to use the structures too (Connolly-Newman, 2013).
8. Accompany the implementation of wildlife crossing structures with research to investigate wildlife use and learn about possible preferences of the different target species with regard to the type and dimensions of the crossing structures.
9. For highways with a median, consider the structures for the two travel directions as one wildlife crossing structure rather than as two separate ones. This implies that the type and dimension of the crossing structures for the two travel directions should generally match, and that the structures should be at the same level allowing wildlife to see through both structures when they approach the highway.
10. Create a very gradual, preferably level, approach for wildlife when approaching wildlife crossing structures (perhaps around 10 degrees maximum). Avoid steep slopes (uphill or downhill), allow wildlife to see the sky and vegetation through or across the structure. Note that gradual approaches may not always be possible, or that it may require recontouring the approaches and restoring the soil and vegetation afterwards. Also consider the surrounding terrain. If the surrounding terrain has a lot of topography (steep slopes) it is more acceptable to have steeper approaches to a crossing structure than when the surrounding terrain is flat.

2.4.6. Multiple Use Structures

Structures that are primarily intended to pass water, people (trails), or motorized vehicles (farm equipment, traffic on minor roads) can be modified or designed to also allow wildlife use under or over a higher volume highway (Clevenger & Huijser, 2011). This is especially true for species that are adapted in multi-functional landscapes (e.g. white-tailed deer, mule deer) with a high degree of human disturbance (van der Ree & van der Grift, 2015). However, human co-use of wildlife underpasses is associated with reduced wildlife use for certain sensitive species, and wildlife may shift their movements to the night when human disturbance is less (van der Ree & van der Grift, 2015). Furthermore, combining wildlife and people in one structure is likely to increase the probability of human-wildlife conflicts. Finally, structures that primarily serve other functions than wildlife are almost by definition in suboptimal or perhaps marginal or unsuitable locations for wildlife, and, at the very least, it is unlikely that all habitats will be connected if the structures primarily serve people or pass water (Smith et al., 2015). If the structure is not located where wildlife come close to the highway and where they want to cross the highway, a structure may not receive substantial wildlife use. In general, combining wildlife use with human use is still considered experimental. Combining human use with wildlife species that are sensitive to human disturbance, rare, threatened, or particularly dangerous to people (e.g. grizzly bears) should, in general, be avoided (van der Ree & van der Grift, 2015). However, bearing these limitations in mind, it is still considered good practice to adapt existing or design new structures primarily intended to pass water so that they are also suitable for wildlife species. If the space (width, height) allows, aquatic, semi-aquatic and terrestrial habitat should be provided, and the structure should preferably be "bottomless" to allow for natural stream characteristics.

Suggestions and recommendations:

1. When the target species are common, adapted to living in multifunctional landscapes and associated levels of human disturbance, and if the species are not particularly dangerous to people (e.g. deer), one could consider experimenting with combined wildlife and human use. However, recognize that wildlife use may be lower than for a designated wildlife crossing structure, and that the wildlife use may shift to the darker hours when human use is low (van der Ree & van der Grift, 2015).
2. When the target species are rare, threatened, indicative of undisturbed habitat and sensitive to human disturbance, and if the species are known to be dangerous to people (e.g. grizzly bear), one should probably build separate structures for people and wildlife (van der Ree & van der Grift, 2015).
3. For multiple use structures (humans and wildlife), design the structures in such a way that people or vehicles are located on one side of a structure (i.e. not in the middle). Also consider a berm tree trunks, vegetation, or other physical and visual barriers between the "path" used by humans and the rest of the structure reserved for wildlife. These measures minimize disturbance for wildlife on the rest of the structure (van der Ree & van der Grift, 2015).
4. Do adapt or design structures primarily built for water to also allow for wildlife use. However, if these are the only wildlife crossing opportunities that are provided, species associated with higher and drier habitats will lack crossing opportunities.
5. In water crossings, provide a "bottomless" structure that allows for natural stream dynamics (see the aquatic literature review). In addition, if the width and height of the structure allows, provide not only aquatic wildlife habitat, but also habitat for semi-aquatic and terrestrial species. Wildlife paths may be situated on either side of the stream or both sides. Wildlife paths for large mammals should be > 8 ft (2.4 m) wide (Clevenger & Huijser, 2011) and should preferably have a clearance (height) of 4 meters or more.

3. LITERATURE REVIEW: AQUATIC

3.1. Impacts of Roads and Barriers on Fish and Other Aquatic Species Movement

Fish and other aquatic species move throughout their range from streams and rivers to connected tributaries, lakes or wetlands. In cases of anadromous species like salmon, these movements may cover hundreds of miles as fish migrate from the ocean to spawning tributaries. In Teton County, native fish like cutthroat trout may move only a few tens of feet a day for the purpose of feeding and seeking cover; but, over the course of a full year, that same trout may move miles to access spawning grounds or to seek refuge in cooler water.

Most watersheds outside of protected areas have many instream structures throughout them, such as culverts or low-head dams (e.g. irrigation diversions). Data presented at the National Fish Passage Summit held on February 15 and 16, 2006 in Denver, CO indicated there are over 2.5 million barriers from culverts, dams and canals on streams and rivers in the United States. In some cases, these structures isolate aquatic habitats, resulting in loss of species in extreme cases. For example, white-spotted char were absent upstream of dams at 17 of 52 study sites in Japan (Morita and Yamamoto, 2002), and four minnow species were extirpated upstream of a dam in a prairie stream in the United States (Winston et al. 1991). Maitland (2016) assessed instream habitat characteristics, such as mean depth, water velocity, percent fines, and fish communities from 33 culverted, bridged, and reference streams in west-central Alberta. The majority of fish species exhibited significantly lower densities in upstream habitats as compared to downstream habitats, including a significant reduction in slimy sculpin densities in culverted streams. Barriers can also increase genetic and reproductive isolation of aquatic species (McKay, 2013).

Although the majority of studies focus on impacts of roads and road-crossings to fish, there are a growing number of studies in the past decade or so on other aquatic species such as amphibians. Honeycutt et al. (2016) investigated potential impacts of culvert design and increased sediment loading near roads on Idaho giant salamander. Study results suggested survival of Idaho giant salamander could be reduced in areas with increased sedimentation. Beebee (2013) reviewed a number of different studies from four continents focused on impacts of roads on amphibians. Beebee (2013) found that amphibians make up between 6% and > 90% of vertebrate kills on roads. His review also showed roads can reduce amphibian diversity within 50 to 2000 meters of them.

Culverts create barriers to upstream movement of fish and other aquatic species in a number of different ways including when they (1) are undersized and create excessive water velocity; (2) have insufficient water depth; (3) are physically too small for the species of fish or aquatic species; (4) have large outlet drops or are “perched”; (5) are blocked by debris jams; or (6) are too long (Baker and Votapka, 1990; Votapka, 1991; Fitch, 1995; Warren and Pardew, 1998; Ottburg and deJong, 2006; Bouska and Paukert, 2009; Burford et al., 2009; and Goerig et al. 2016). In some cases, it is the combination of two or more of these conditions that make ordinarily passable conditions impassable or problematic. For example, a structure may have a small outlet drop that by itself, may not create a barrier; however, if the water velocity is relatively fast in the structure, then the combination of fast water and a perched entry requiring a fish to leap can make it more difficult or impossible for a fish to swim upstream.

More recent studies point to other factors, both behavioral and physical, that contribute to passage success or failure at structures. Goerig et al. (2016), investigated brook trout passage through 13 culverts, including corrugated metal pipes (CMPs), concrete and polyethylene types, using passive integrated transponder (PIT) tags. The CMPs were classified as “rough” and all other types were classified as “smooth” with regards to bed roughness. The study found passability was most strongly associated with culvert type, and that “rough” culverts were more passable than “smooth” culverts, especially for smaller fish. Researchers speculated the hydraulic complexity in rough culverts may be the reason for increased passage, and corrugations in the rough culverts may have been used as resting areas for small fish. The study showed passage was not tied to one factor, but rather several, and passage success was influenced by interactions between behavioral and physiological aspects of fish swimming performance. Passage success decreased with increased slope, was less at culverts with deeper outlet pools, and declined with increasing velocity. Passage increased with temperature towards an optimum around 14 to 15 C, then decreased slowly to 18C (the highest temperature measured).

In some cases, barriers to fish and aquatic species movement from culverts or other structures are purposely left in place or constructed to protect native species from non-native species. Barriers are a relatively common conservation strategy to protect native cutthroat trout from non-native rainbow and brook trout in Montana. In Canada, a fish migration barrier was constructed to prevent the migration of suckers and northern pikeminnow from a reservoir into the Salmo River (Baxter et al., 2011). Selective barriers are used in the Great Lakes region to block sea lamprey from accessing streams, yet allow leaping fish species such as trout to pass over them (Lavis et al., 2003).

3.2. Impacts of Roads on Aquatic Habitat

Barriers, including culverts, and roads not only impact movement of fish and other aquatic species, but also can alter flow regimes, surface and groundwater hydrology, local geomorphology and nutrient cycling (McKay, 2013).

3.2.1. Alterations to Flow and Hydrology.

Roads can alter hydrologic processes, including the natural surface and subsurface flow paths that transmit water, sediment, and nutrients to and through watersheds, wetlands, streams and rivers (Trombulak and Frissel, 2000; Forman et al., 2003; Wemple and Jones, 2003; Coe, 2004). Some impacts from roads include channelization of streams and intermittent channels, changes to flood dynamics, and changes to groundwater-surface water interactions.

Roads can penetrate soil horizons that are conduits for water flows from groundwater to surface water and disrupt these pathways. Groundwater temperatures do not fluctuate as much as surface water temperatures and typically maintain more constant temperatures throughout the year; therefore, they can help regulate stream temperatures which is an especially important process during low flow periods (Giller and Malmqvist, 1998; Edwards, 1998). Bull trout seek habitat with groundwater upwelling or downwelling for spawning sites (Baxter and Hauer, 2000).

3.2.2. Alterations to Geomorphology (Physical Alterations to Shape, Slope, and Sediment Characteristics)

Debris and sediment movement across landscapes can be altered by roads (Jones et al., 2000). Road-stream crossings can increase the accumulation of fine sediment downstream of the crossings with potential impacts to salmonids, such as brook trout (Lachance et al., 2008). However, if proper best management practices (BMPs) are used at crossings, the sediment load can be minimized (Morris et al., 2016).

During the design phase for a new crossing, properly assessing the reach-scale stability of the stream where the crossing will be placed is important. Castrol and Beavers (2016) described how instream structures act as “ad hoc” grade controls, and that removal and/or replacement can negatively affect habitat and passage by changing the vertical control of the stream channel where the structure was installed. They suggested designers need to evaluate stream channel evolution through the use of longitudinal profile analyses (the topography of a stream). And, in cases where there may be vertical instability, mitigation measures such as the placement of large woody debris or other roughness elements may be necessary as grade controls.

3.3. Measures to Reduce Impacts on Aquatic Habitat and Connectivity

3.3.1. Mitigation for Aquatic Habitat

Best practices for reducing impacts from roads on aquatic habitat range from simply avoiding the waterbody and adjacent habitat completely, to bio-engineered solutions, such as engineered wetlands to treat contaminants prior to allowing them to enter a waterbody, to highly engineered or technical solutions, and finally to changes in operation and maintenance practices.

The best approach to protect aquatic habitat and connectivity is to ensure the roads are constructed a sufficient distance from them or, in retrofit situations, to move the road to avoid interfering with it. If avoidance is not feasible, which is often the case, then the next best approach is to create a sufficient natural or semi-natural buffer between the road and the habitat. A well-designed and constructed buffer will capture, store and process pollutants prior to them entering a waterbody. The width of the buffer will vary depending on the features of the landscape such as type of vegetation, soils and slope, as well as the volume and characteristics of the storm water. In North Carolina, trout waters must have a minimum 25-foot of undisturbed buffer on either side (NCDT, 2003). The Washington Department of Fish and Wildlife recommends buffer widths ranging between 150 and 250 ft depending on the type of stream and its characteristics (Saldi-Caromile et al., 2004).

In many situations, avoidance is not possible or there is simply not enough room to maintain a preferred natural or semi-natural buffer. In these cases, engineering solutions (such as sediment traps), may be required to limit the concentration and quantity of sediment or other contaminants entering the waterbody. Other approaches involve changing operation and maintenance practices. For example, it may be possible to reduce the volume of sand spread over bridges as compared to other sections of road because sediment on bridges can be more easily flushed into nearby aquatic habitat.

3.3.2. Mitigation for Aquatic Connectivity (Crossings)

From an aquatic species standpoint, the goal of a new crossing should be to ensure passable conditions are maintained throughout the engineering life of a crossing. This goal implies the "best" approaches are crossings that prevent passage problems, such as outlet drops or elevated velocities, from developing once the crossing is in operation. In some cases, passage problems are created when crossings restrict or impede natural channel function or stream continuity, thus degrading the stream channel bed near them.

There are a range of options available for design and construction of road-stream crossings specifically for aquatic organism passage and many good design manuals such as the FHWA document: *HEC 26 -Culvert Design for Aquatic Organism Passage*, the USDA manual: *Stream Simulations: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*, and state guidance like the Washington Department of Fish and Wildlife design manual: *Water Crossing Design Guidelines (2013)*. When possible, using long-span bridges that are wide enough to allow for full floodplain function through them allows for the natural function of the stream or river and riparian area. These types of structures will also provide connectivity for both terrestrial and aquatic species. However, long-span bridges are the costliest option for road-stream crossings which can in some cases make them infeasible.

Other large structures that fully span the stream or river and its banks provide the next best solution to ensure long-term passage of fish and aquatic species, and are less expensive than long-span structures like bridges. In retrofit cases, it may be more feasible to remove the existing infrastructure and reinstate the natural system or replace it with a crossing structure designed using a "stream-simulation" approach (USDA, 2008). The stream-simulation approach relies upon the following basic principle:

> …designing crossing structures (usually culverts), that creates a structure that is as similar as possible to the natural channel. When channel dimensions, slope and stream bed structure are similar between the crossing and the natural channel, water velocities and depths also will be similar. Thus, the simulated channel should present no more of an obstacle to aquatic animals than the natural channel (USDA, 2008).

Stream-simulation culverts can be designed and constructed using a variety of different culvert types and shapes including round, bottomless arches, box, and squash (or elliptical) shapes amongst others (USDA, 2008; Barnard et al., 2015). In addition, these designs can utilize single or multiple structures. Multiple structure designs typically use a primary structure for the main channel and additional structures to convey higher flows that activate side-channels or floodplain areas.

Recent studies investigated the effects of "stream simulation" on aquatic species movement, habitat and channel form. In Alaska, crossings on a salmon stream in Anchorage were replaced with new crossings designed to mimic natural channel conditions. The study used a pre-post monitoring scheme to evaluate the response of salmon in the system to the new crossings. Monitoring showed a 300% increase in coho salmon escapement from pre- to post restoration, from 481 adults in 2008, to approximately 1500 adults on average between 2009 to 2013 (Myers and Nieraeth, 2016). A study in Washington State evaluated 50 culverts designed following stream-simulation approaches by comparing channel bed and hydraulic conditions between culvert (treatment) reaches and reference reaches. The study found sediment size and gradation, velocity at the 2-year recurrence interval (RI) flow, and flow widths (width of water at surface) during the 2-year RI flow were similar between culvert and control reaches. Culvert reaches; however, were not as likely to maintain channel complexity because it is difficult to accommodate natural channel forming features from woody debris or vegetative processes within them. The study also found stream simulation culverts did not deteriorate from large flood events observed during the study, which implies that this approach maintains flood resiliency (Barnard et al., 2015).

In some situations, such as retrofit scenarios, baffles can be installed within the culvert barrel to increase water depth, decrease velocity and increase velocity diversity (Blank, 2010). There are a number of different types of baffles including offset baffles, slotted weir baffles, weir baffles, and spoiler baffles (Ead et al., 2002). McDonald and Davies (2007) investigated the ability of common jollytail and spotted galixias to pass upstream through an in-situ pipe culvert modified through the installation of spoiler baffles. Results indicated jolly tails were ten times more likely to pass through when baffles were present compared to when baffles were absent. Across all velocities, common jollytails and spotted galaxias were, respectively, 86 and 73 times more successful with the most complex baffle arrangement compared to control conditions (baffles absent). Success for both species decreased at higher velocities under control conditions.

3.4. Other Benefits of Larger Structures (Climate Change)

Designing larger spans to better accommodate stream and floodplain function as well as fish and wildlife also makes the crossing more resilient to future large flood events. One of the most promising mitigation techniques for aquatic species under changing climates is to increase habitat connectivity (Lawler et al., 2009). Climate forecasts for the Greater Yellowstone Region indicate a shift towards higher temperatures which could result in more precipitation as rain instead of snow and changes to the amount and timing of spring runoff (NPS, 2017). Based on the last 50 years of recorded climate data in Yellowstone Park, there are 80 more days with above freezing temperatures at the northeast entrance; and approximately 30 fewer days per year with snow on the ground than in the 1960s.

Road crossing design requires estimation of a flood flow to determine size of crossing structures and road surface elevations amongst other road features. In the United States, the design flood flow for most county roads is the 50 year recurrence interval (RI) flood. This value is typically determined based on empirical data from the past climate record using either records of gaged data or regional regression equations. With changing climates affecting future flood size and frequency, many countries have already begun to change their design flood RI, or their road design practices, based on how the future climate may look versus relying upon past climate records. For example, the Norwegian Public Roads Administration is requiring the design elevation for road surfaces be based on a 200-year RI. Danish Road Directorate has made a practice of planning new roads away from locations that have a high risk of flooding (FHWA, 2017).

4. IDENTIFY AND PRIORITIZE POTENTIAL MITIGATION SITES FOR LARGE MAMMALS

4.1. Introduction

The seven road sections (see Chapter 1, Figure 1) were evaluated for three types of parameters: 1. Human safety data based on wildlife-vehicle collisions (this includes wildlife-vehicle crash data as well as carcass removal and incidental carcass observation data), 2. Biological conservation data, and 3. A cost-benefit analyses for different types and combinations of mitigation measures aimed at reducing wildlife-vehicle collisions and providing safe wildlife crossing opportunities. These three types of parameters are summarized in different sections in this chapter. The three types of parameters were then combined to prioritize road sections for potential future mitigation measures.

4.2. Human Safety

4.2.1. Wildlife-Vehicle Collision Data Sources and Species Selection

The researchers used three different datasets to identify road sections that have a concentration of wildlife-vehicle collisions ("hotspots"):

1. Wildlife-vehicle crash data reported by law enforcement personnel. The researchers consider this dataset to be based on "consistent" search and reporting effort in space and time. Thresholds to be included in the crash database are that it needs to be reported to law enforcement, and that the estimated vehicle repair costs are at least $1000 (Huijser et al, 2007a). This means the crash data typically relate to the more severe crashes with large mammals.
2. Carcass removal data reported by maintenance personnel from the Wyoming Department of Transportation. The researchers consider this dataset to be based on "consistent" search and reporting effort in space and time. Thresholds to be included in the carcass removal database are that the carcass needs to be large enough to be considered a danger or distraction to drivers and that it needs to be visible from the road (on road or in right-of-way). This means the carcass removal data typically relate to large mammals. The number of recorded carcasses tends to be much higher than the number of reported large mammal crashes.
3. Nature Mapping Jackson Hole (NMJH) / Jackson Hole Wildlife Foundation (JHWF) wildlife-vehicle collision data (combination of wildlife-vehicle crash data (law enforcement personnel), carcass removal data (WYDOT), and incidental observations by the public (Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation, 2017a). The data requested and received were limited to terrestrial wildlife species coyote size and larger. This dataset includes the crash and carcass removal data (see previous two points), supplemented by incidental observations from the public and WYG&F personnel. Our selection was restricted to species coyote size and larger. This means that

it also included (slightly) smaller species than the crash and carcass removal data. In addition, the number of records was greater than that for the individual crash or carcass removal data sets. This means that while the number of observations in the Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation database is still an underestimate, it is closer to the true number of (large) animals that are hit by vehicles than estimates based on the number of records in the crash or carcass removal database. However, because of the additional incidental observations, the researchers consider this database to not have the same level of consistent search and reporting effort in time and space compared to the crash and carcass removal data.

4. Existing wildlife-vehicle collision statewide hotspot maps per species for deer, elk and moose (2011-2015) based on WYDOT crash and carcass removal data (Riginos, 2017). The road sections were classified for lowest to highest densities of collisions (dark green - light green – yellow – orange – red) (see Riginos (2017) for further details).

The first three data sets all related to the same 10-year period: 1 January 2006 through 31 Dec 2015. The researchers selected wildlife species that are large and heavy enough to be considered a concern for human safety (≥100 lbs (≥45.4 kg)) (Table 3). Domesticated species (e.g. cattle, horses) were excluded as the movements of domesticated species are or should be controlled by humans. Medium and small sized species and unidentified species were also excluded from the hotspot analyses as their body size and weight did not pose a substantial threat to human safety. Some of the collision data were based on coordinates rather than 0.1 mile reference posts. The observations with coordinates were projected onto the nearest 0.1 mile road section road. For an observation to be included and assigned to a 0.1 mile road segment, the maximum distance from the road was 100 m.

Table 3. The species that were present in the three wildlife-vehicle collision databases.

Species	Total		Carcass		Crash		JHWF Collision	
	N	%	N	%	N	%	N	%
Large wild mammal species								
Mule deer	2387	69.51	843	75.81	0	0.00	1544	73.28
Elk	610	17.76	184	16.55	66	30.70	360	17.09
Moose	261	7.60	68	6.12	23	10.70	170	8.07
Deer sp.	124	3.61	0	0.00	124	57.67	0	0.00
White-tailed deer	27	0.79	11	0.99	0	0.00	16	0.76
Pronghorn	7	0.20	1	0.09	1	0.47	5	0.24
Bighorn sheep	6	0.17	2	0.18	1	0.47	3	0.14
Black bear	6	0.17	2	0.18	0	0.00	4	0.19
Grizzly bear	2	0.06	1	0.09	0	0.00	1	0.05
Gray wolf	2	0.06	0	0.00	0	0.00	2	0.09
Bison	1	0.03	0	0.00	0	0.00	1	0.05
Mountain lion	1	0.03	0	0.00	0	0.00	1	0.05
Subtotal	3434	100.00	1112	100.00	215	100.00	2107	100.00
Other species								
Coyote	21		17		0		4	
Red fox	9		9		0		0	
Raccoon	8		8		0		0	
Horse	3		2		1		0	
Porcupine	2		2		0		0	
Skunk	2		2		0		0	
Cattle	2		1		1		0	
Owl	1		1		0		0	
Unknown	11		11		0		0	
Not recorded	468		0		468		0	
Other wild species	4		0		4		0	
Subtotal	531		53		474		4	

4.2.2. Seasonal Distribution and Hour of Day of Wildlife-Vehicle Collisions

The carcasses were most frequently recorded in the winter and early spring (December through April) and in the summer months (June and July) (Figure 8). The crashes were most frequent in July and also in the winter and early spring (Figure 8). This seasonal pattern is different from the typical seasonal distribution in North America where there is typically a peak in the fall period and a smaller peak in the early spring (Huijser et al., 2008). Factors that may influence the atypical seasonal distribution of large wild mammal-vehicle collisions in Teton County include the fact that the area hosts important winter habitat (especially for mule deer and elk), that some animals migrate to higher elevation areas in summer, that major migration routes cross through the area, and that the area is both a winter and summer destination for tourists which results in substantial traffic in winter and very substantial traffic in summer.

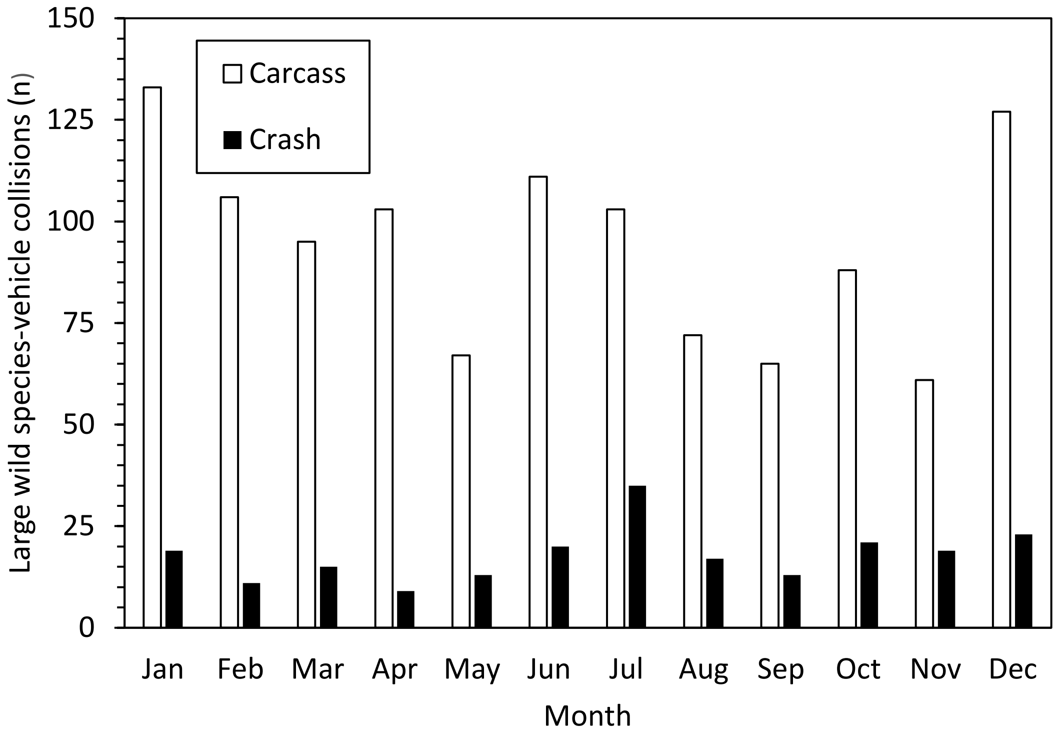


Figure 8. Large wildlife species-vehicle crashes and carcasses by month (WYDOT crash data and WYDOT carcass removal data).

Large wild mammal-vehicle crashes occurred mostly in the evening (6 pm through 11 pm) and early morning hours (5 am through 9 am) (Figure 9).

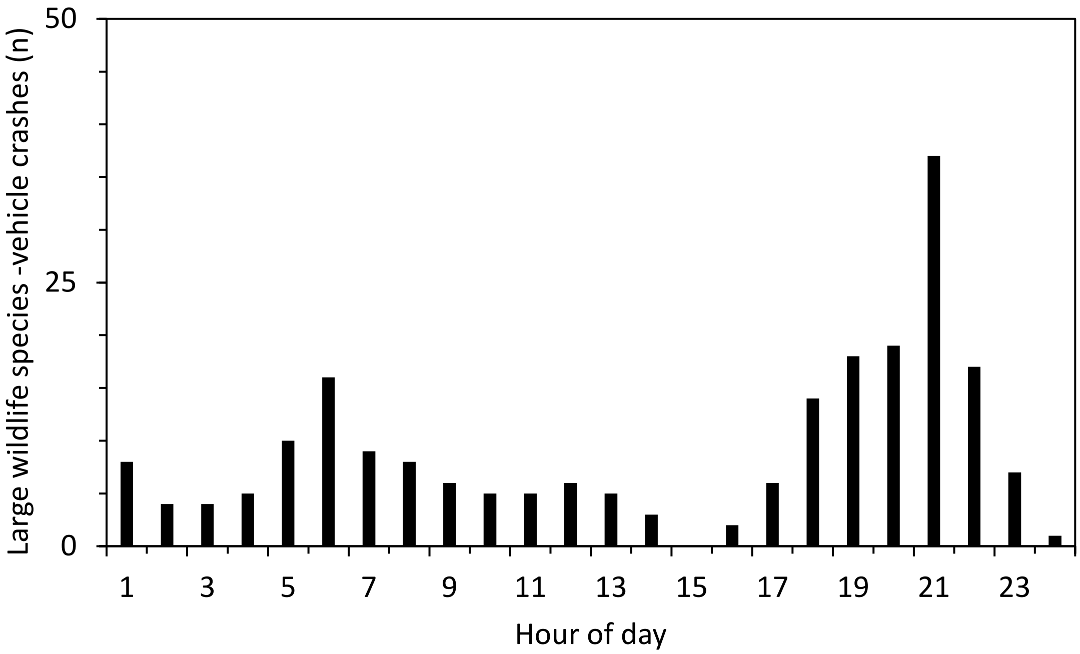


Figure 9. Large wildlife species-vehicle crashes by hour of day.

4.2.3. Wildlife-Vehicle Collision Hotspots

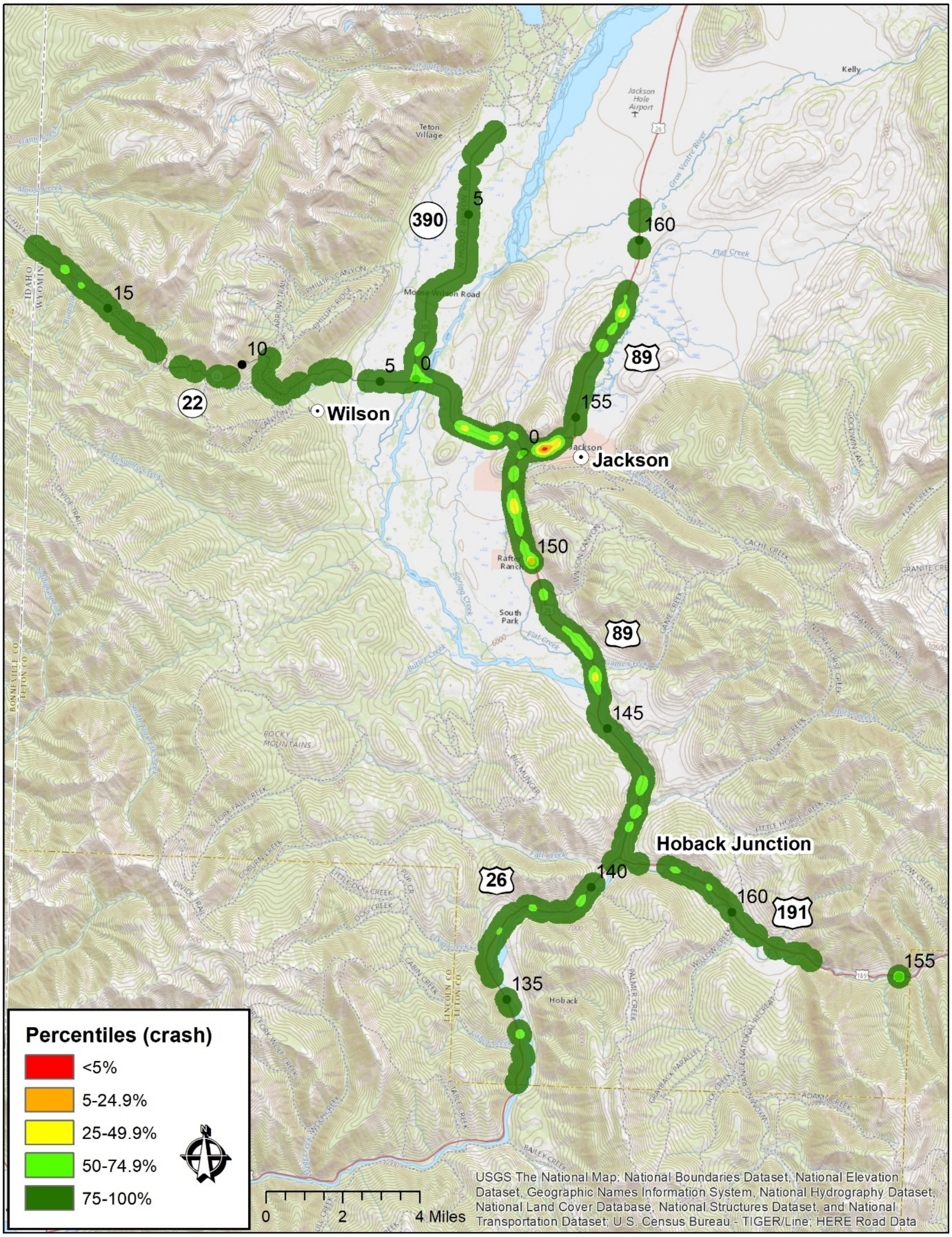
The researchers identified road sections that had the highest concentration of wildlife-vehicle collisions (crash data, carcass removal data, JHWF carcass data). The researchers conducted a Kernel density (ArcGIS Release 9.3) analysis for point features. The analyses included all crash data or all carcass removal data from all seven road sections in Teton County (see Chapter 1, Figure 1). For the Kernel density analyses the researchers divided the study area into a grid with a cell size of 82 x 82 ft (25 x 25 m). The relatively small cell size results in a relatively fine or smooth map. The locations of the crashes and carcasses are considered points and the Kernel density analysis calculates the density of crashes or carcasses in a neighborhood around each cell. Points that are close are weighted more than points that are further away. Consistent with Gomes et al. (2009) we set the search radius at 500 m. On a straight road this basically means that crashes or carcasses that are up to about 0.3 mi (500 m) away are included in the density analyses for each cell.

The researchers considered road sections with no crashes or carcasses and road sections that fell into the two lowest density categories (50-100%; Table 4) (provided that the density is greater than 0) to be “background”. Road sections that had higher densities (“top 50%”) were considered a “hotspot” (i.e. yellow, orange or red in Figures 10,11, and 12 and Appendix A, B, and C).

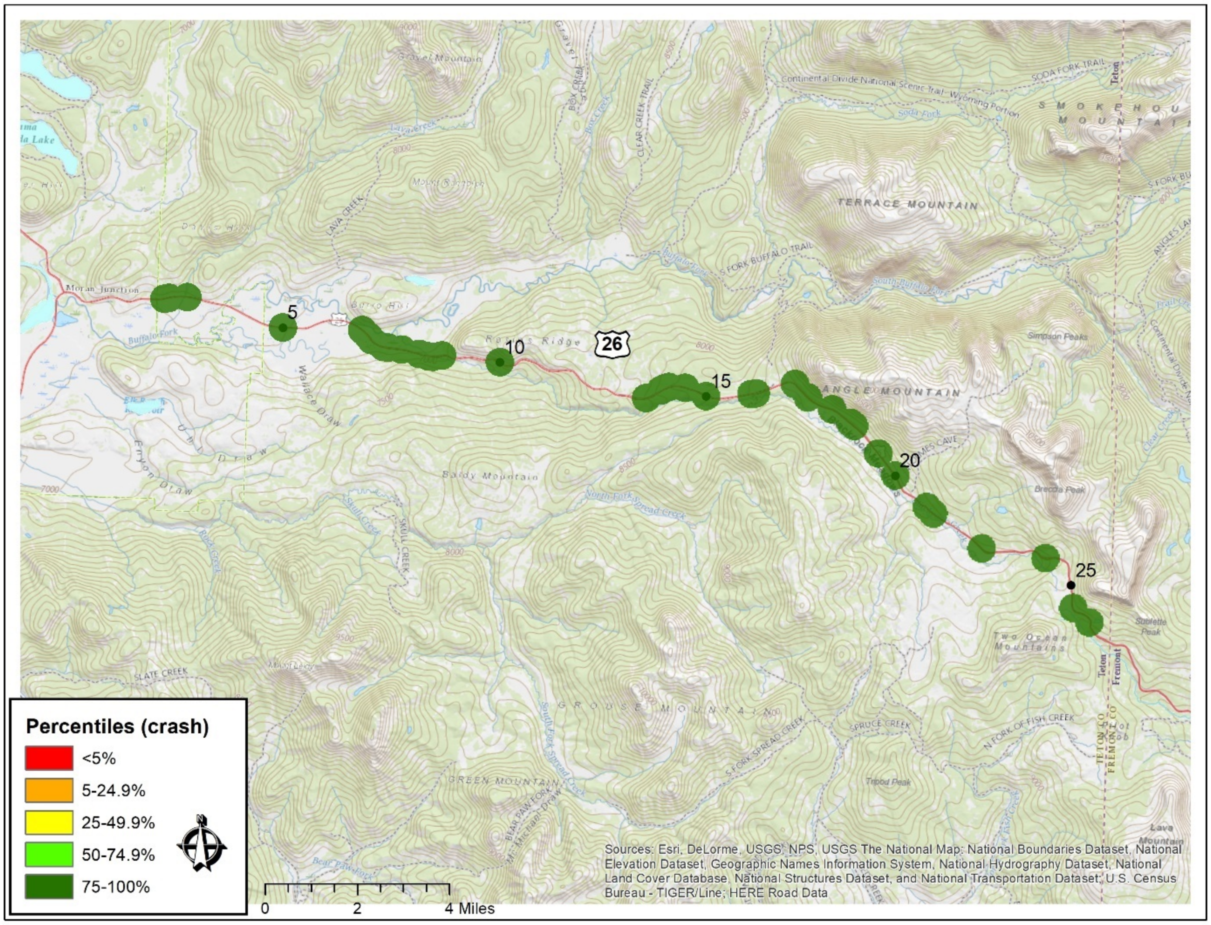
Table 4: The categories used for maps with the hotspots based on the crash data (law enforcement personnel), carcass removal data (WYDOT) and Nature Mapping Jackson Hole (NMJH) / Jackson Hole Wildlife Foundation (JHWF) wildlife-vehicle collision data (Figures 10, 11, and 12).

Percentile categories	Color	Description
n/a	None	Further than 500 m from nearest crash or carcass
75-100%	Light Green	The 25% of the cells with the lowest density (provided that the density is greater than 0)
50-74.9%	Dark green	The next 25% of the cells with the lowest density (provided that the density is greater than 0)
25-49.9%	Yellow	The next 25% of the cells with the lowest density (provided that the density is greater than 0)
5-24.9%	Orange	The next 20% of the cells with the lowest density (provided that the density is greater than 0)
<5%	Red	The 5% of cells with the highest density (provided that the density is greater than 0)

The highway section in Jackson (Broadway) has the highest centration of large wildlife-vehicle collisions (Figures 10, 11, and 12). Note that more detailed maps are included in Appendix A, B, and C. The species most frequently hit on Broadway in Jackson is mule deer (Figure 13). Additional concentrations of collisions are present between Hoback Jct and Jackson and on WY Hwy 22 just west of the intersection with Broadway (Figures 10, 11, and 12).

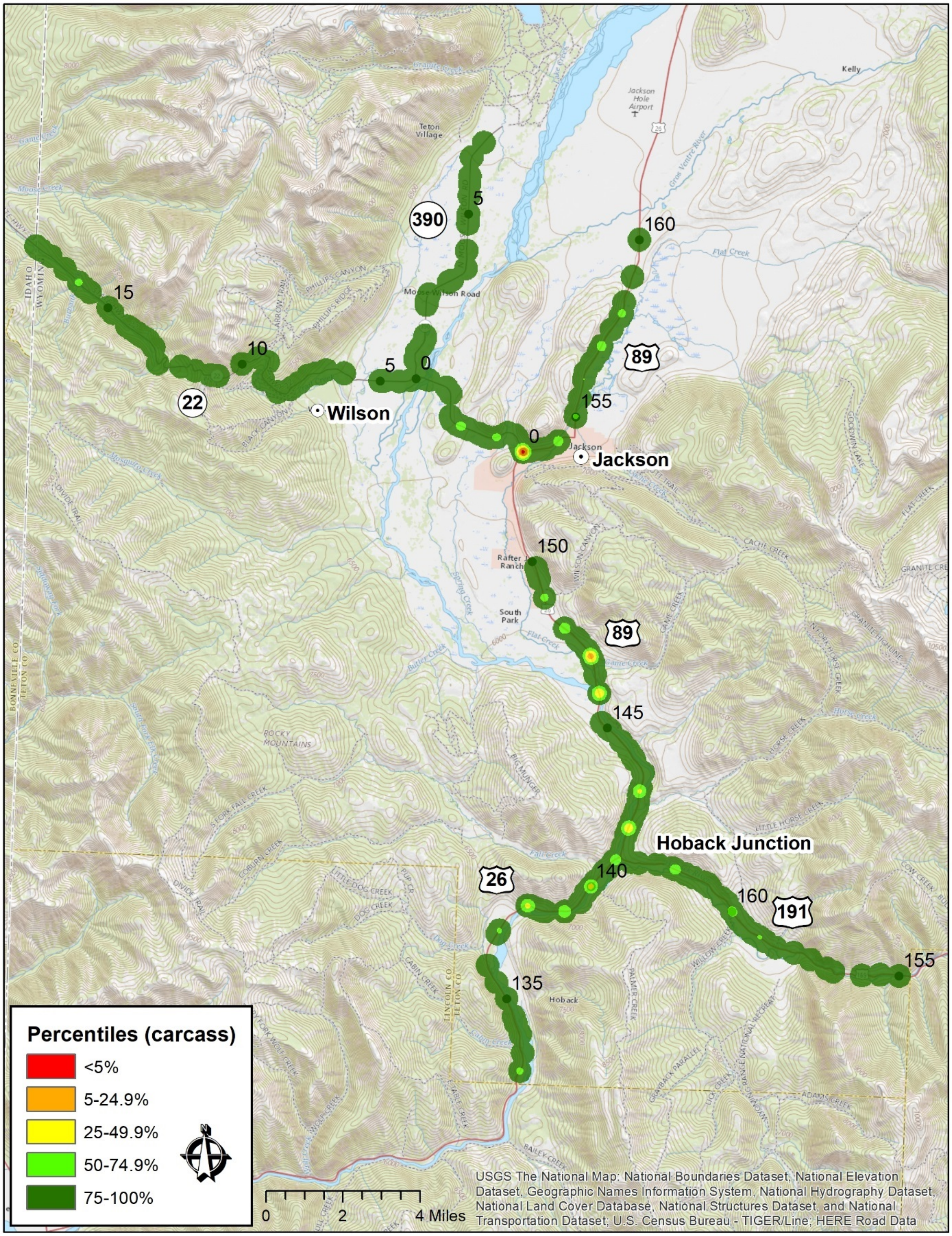


Jackson area

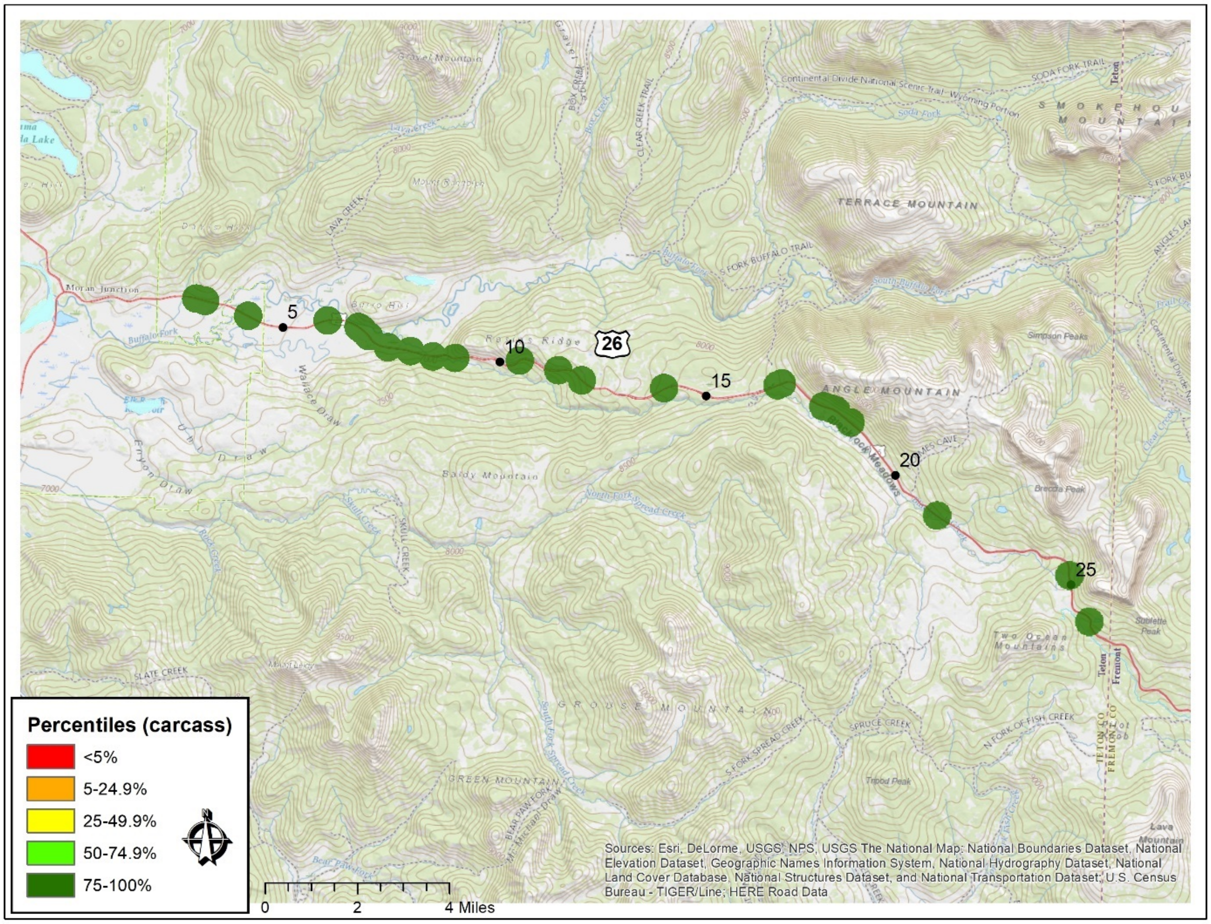


Togwotee Pass

Figure 10. Hotspots for large wildlife species-vehicle crashes (law enforcement).

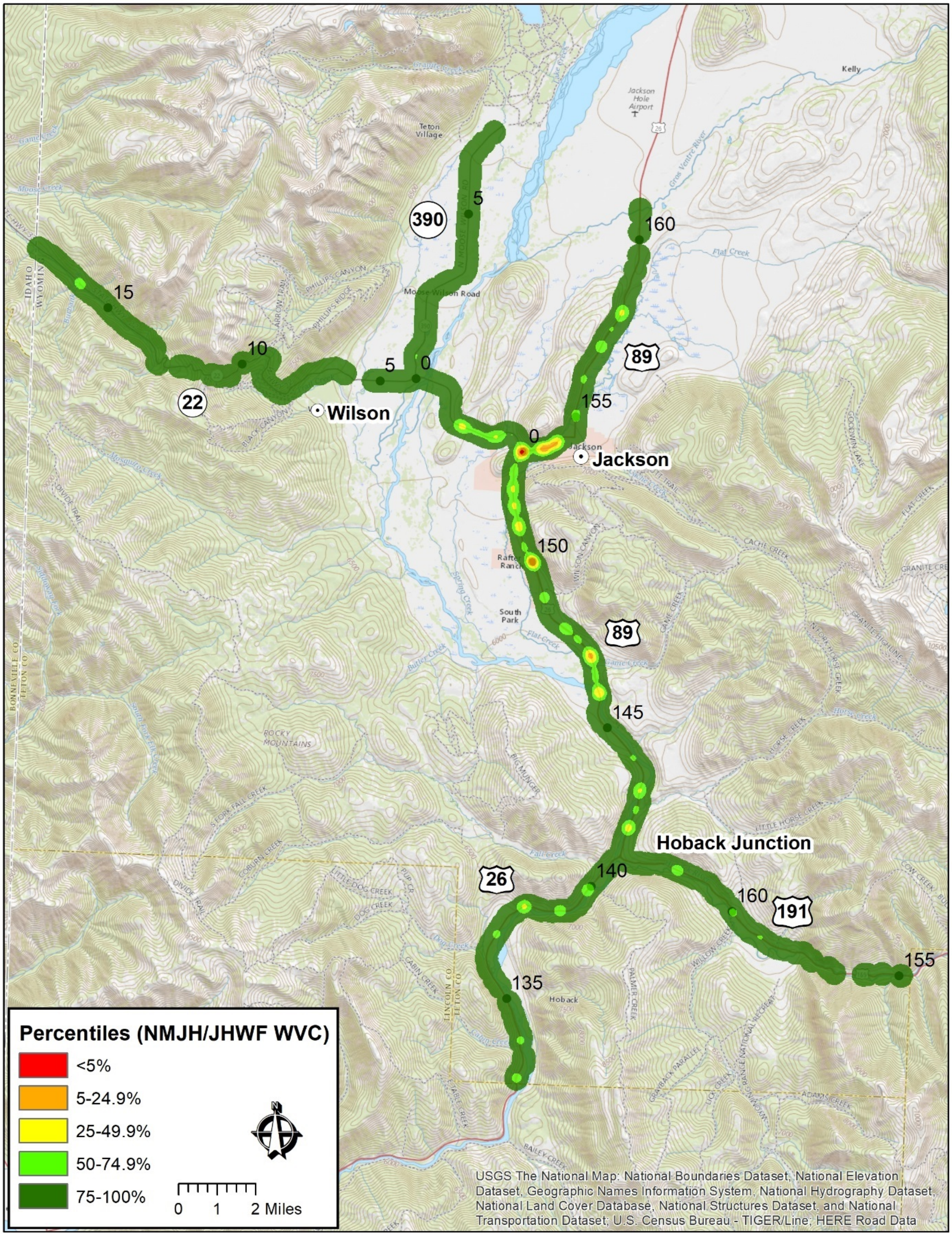


Jackson area

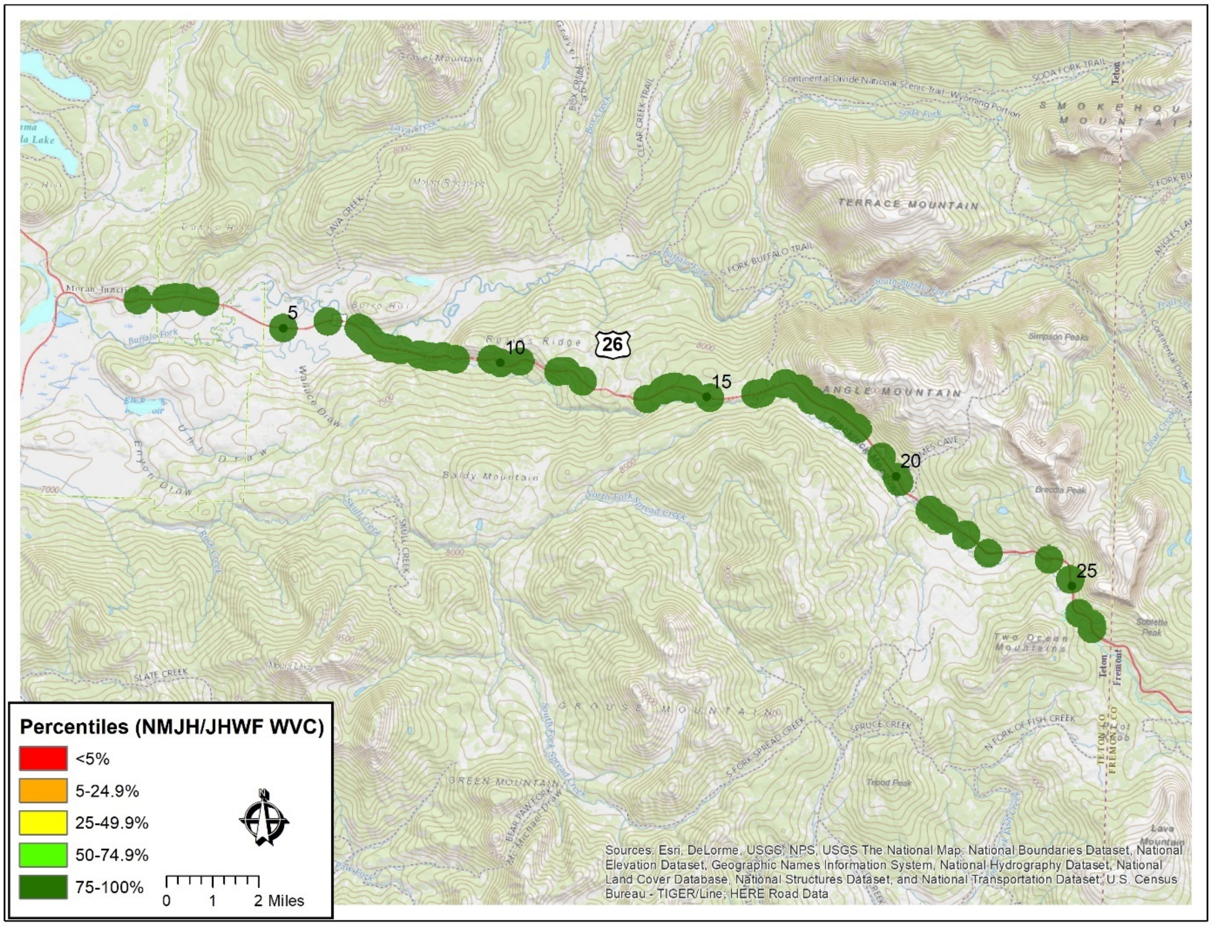


Togwotee Pass

Figure 11. Hotspots for large wildlife species carcass removals (WYDOT).



Jackson area



Togwotee Pass

Figure 12. Hotspots for large wildlife species-vehicle collisions (Jackson Hole Wildlife Foundation, 2017a).

Species-specific analyses showed that the concentration of deer-vehicle collisions was highest in Jackson (Broadway) extending to just south of Jackson, and an additional hotspot was present north of Hoback Jct (Figure 13). Elk-vehicle collisions were most numerous halfway between Hoback Jct and Jackson, and just east of Hoback Jct, with additional concentrations north and west of Jackson (Figure 14). Moose-vehicle collisions were concentrated at the Jct of WY Hwy 22 and WY Hwy 390, and along WY 22 on the west side of Teton Pass (Figure 15).

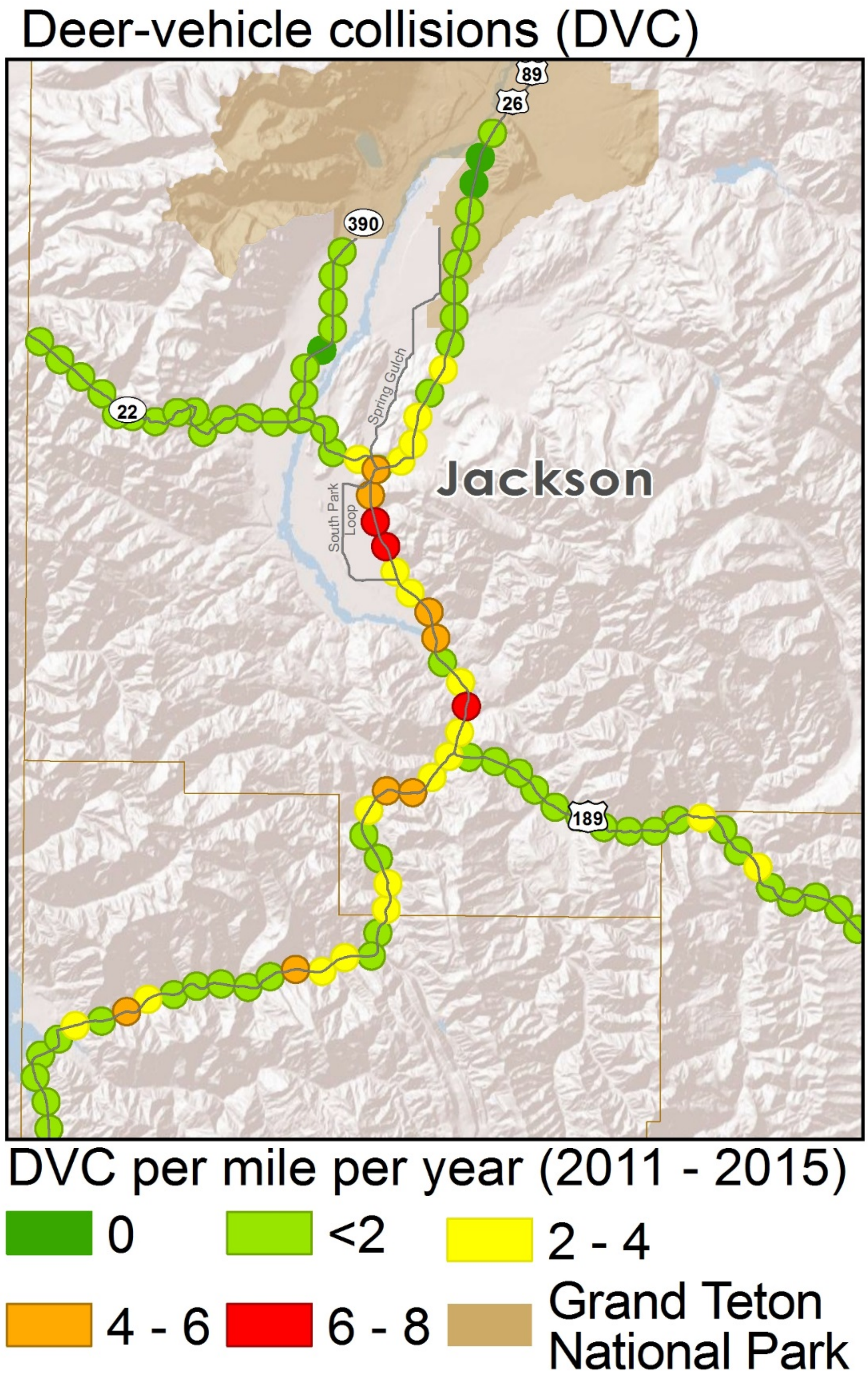


Figure 13. Hotspots for deer-vehicle collisions (Riginos, 2017).

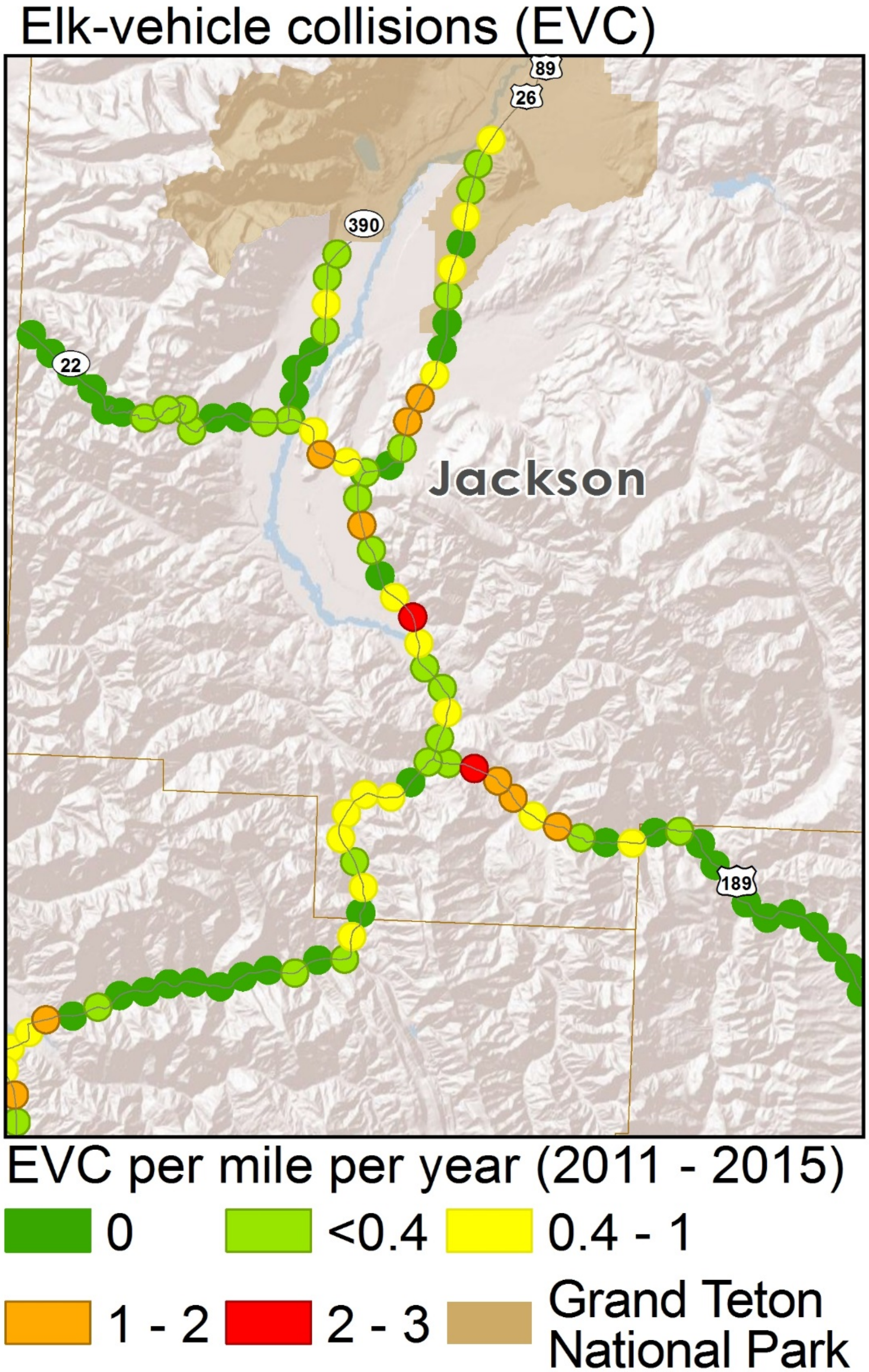


Figure 14. Hotspots for elk--vehicle collisions (Riginos, 2017).

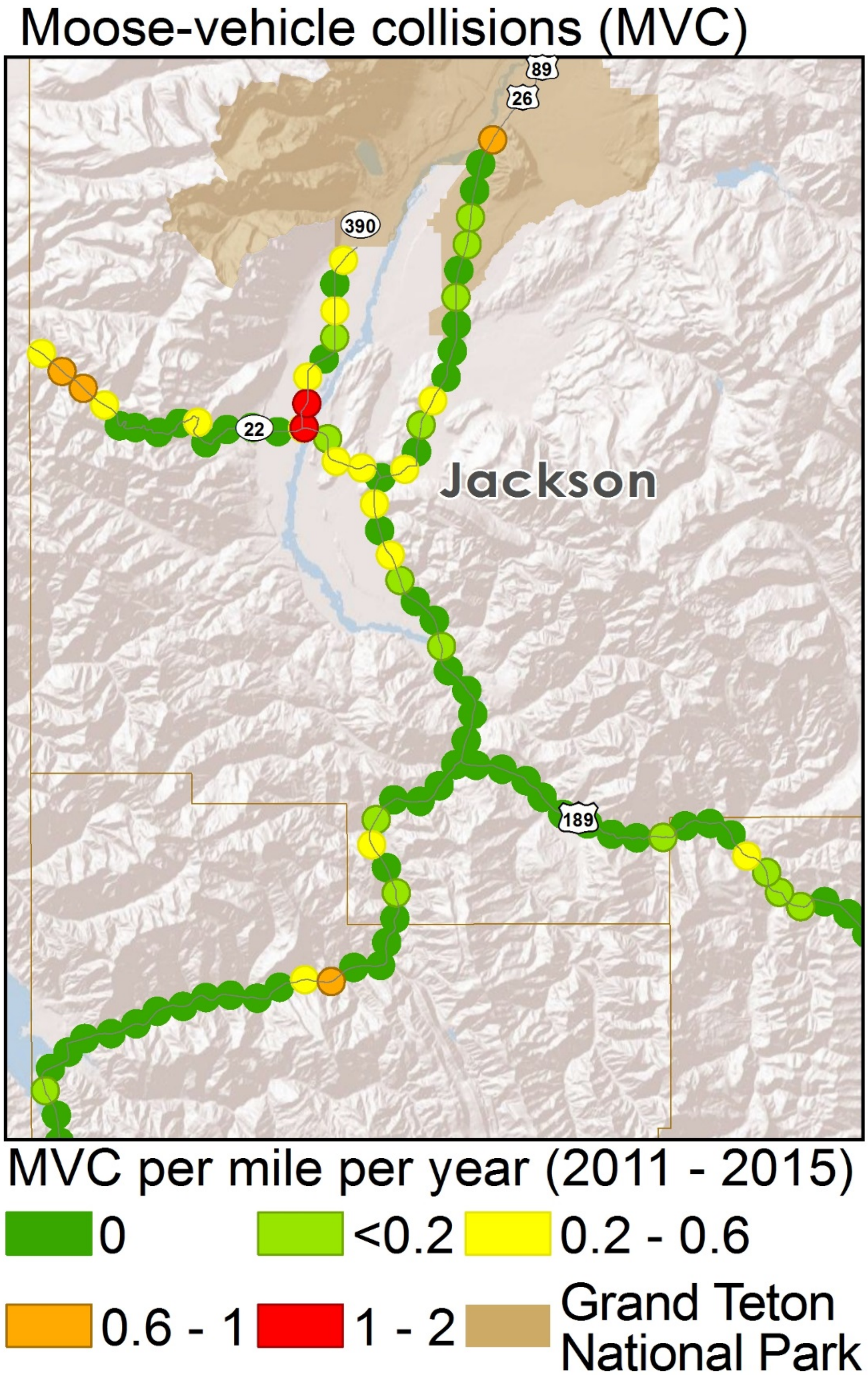
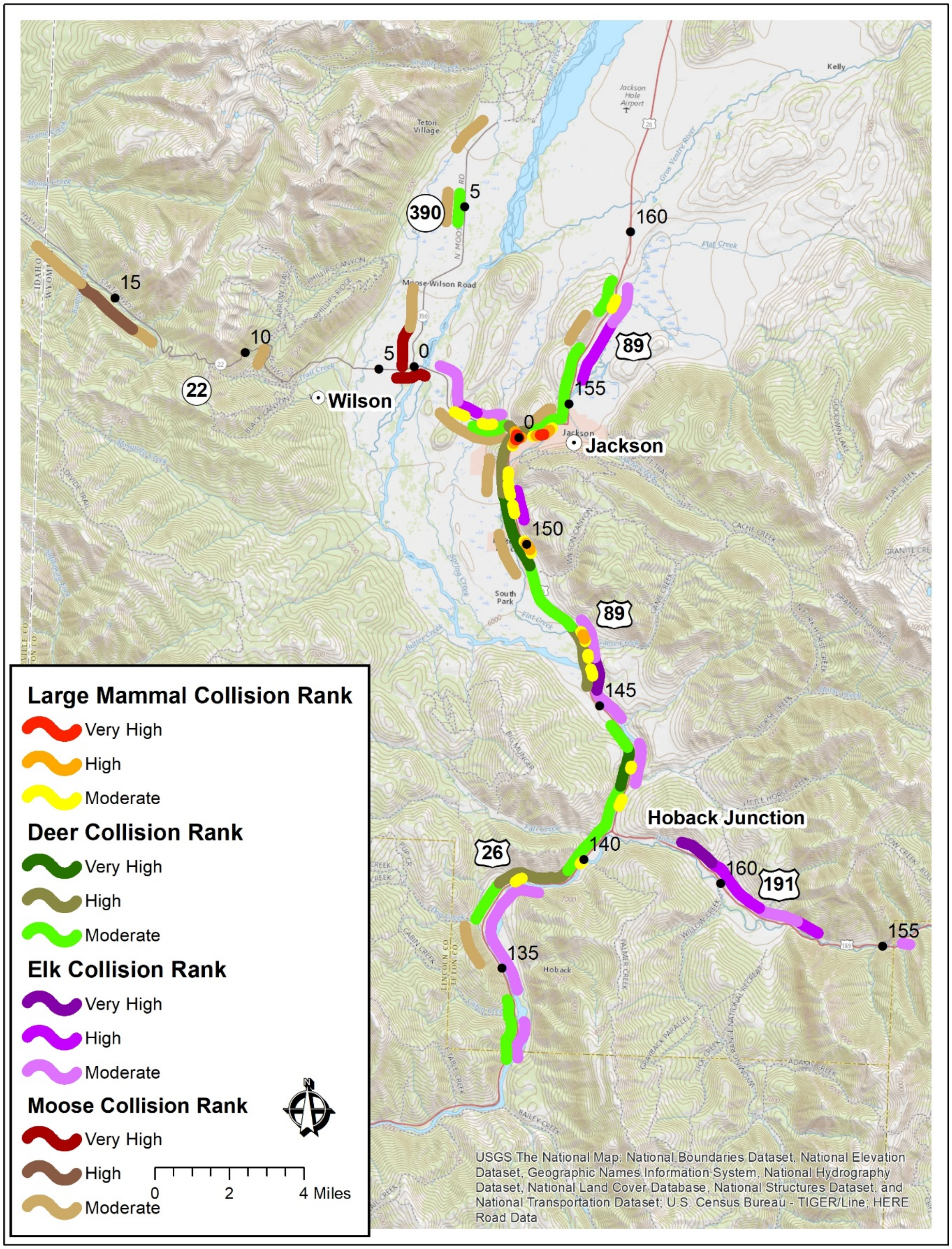


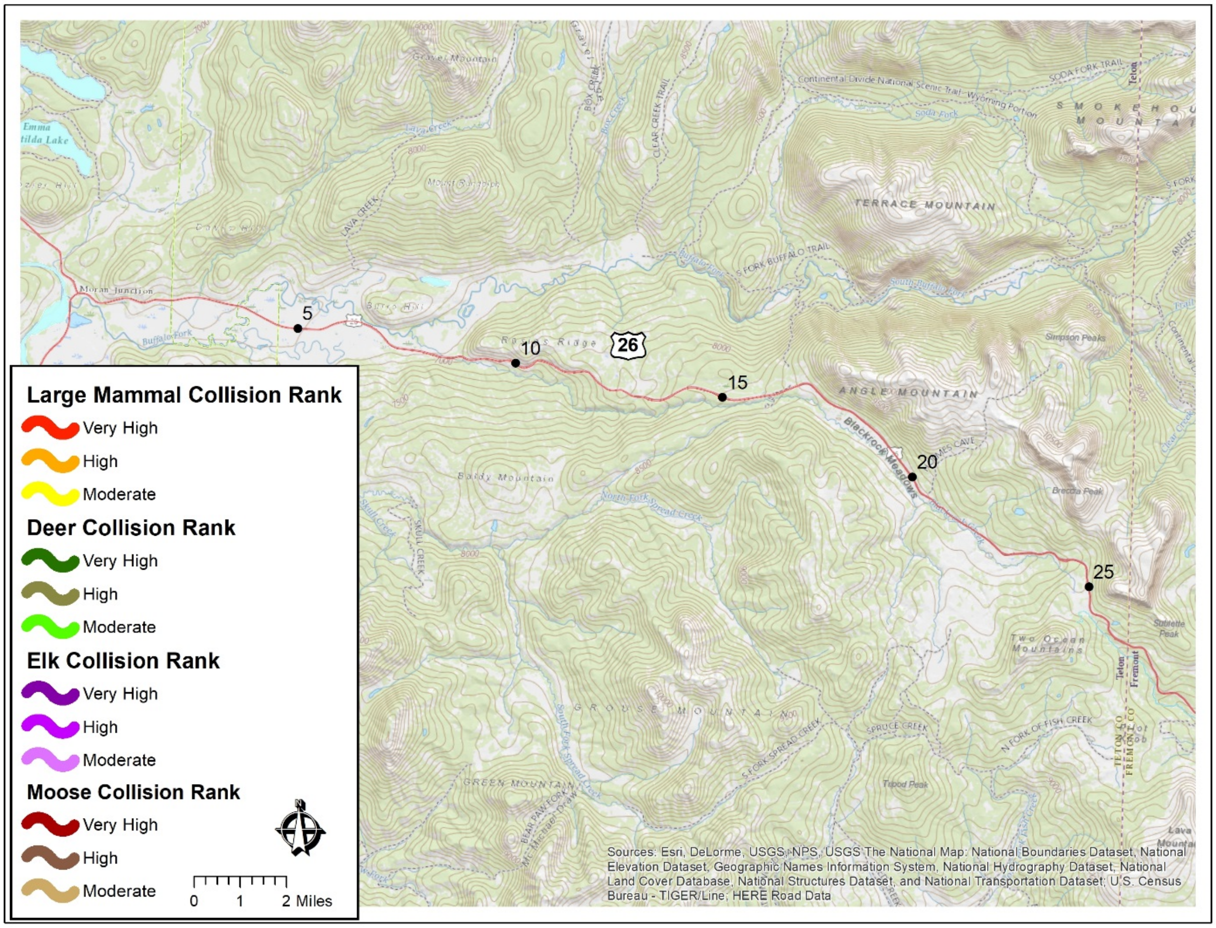
Figure 15. Hotspots for moose-vehicle collisions (Riginos, 2017).

The researchers summarized the large wild mammal-vehicle collision data for the different datasets (Figure 16). The “large mammal-vehicle collision rank” (Figure 16) was based on the categories in Table 4. Whenever either crash data, carcass removal data, or the carcass observation data from Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation along a 0.1 mi long road section was yellow, orange or red (top 50%, see table 4), the road section was identified in yellow, orange or red as well in Figure 16. The color corresponded to whichever of the three datasets had the highest concentration of large mammal-vehicle collisions along that road section. Including the crash data and carcass removal data ensured that no hotspot was missed on roads that are less traveled by the public and others whose search and reporting effort may not be consistent. Also including the data from Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation, meant that, given everything we know about the location of large mammal collisions, we identify the road sections where we have most observations for, regardless of the source, regardless of the search and reporting effort.

Figure 16 also shows the species-specific collision concentrations for deer, elk, and moose. This was based on Figures 13, 14, and 15, and included road sections that were colored yellow, orange or red in Figures 13, 14 and 15. In Figure 16, yellow was labeled as “moderate”, orange as “high” and red as “very high”. Different color schemes were assigned to each of the three species: green for deer, purple for elk, and brown for moose (Figure 16).



Jackson area



Togwotee Pass

Figure 16. Hotspots for large mammal (crash data, carcass removal data, and NMJH / JHWF collision data), and deer, elk, and moose-vehicle collisions (Riginos, 2017).

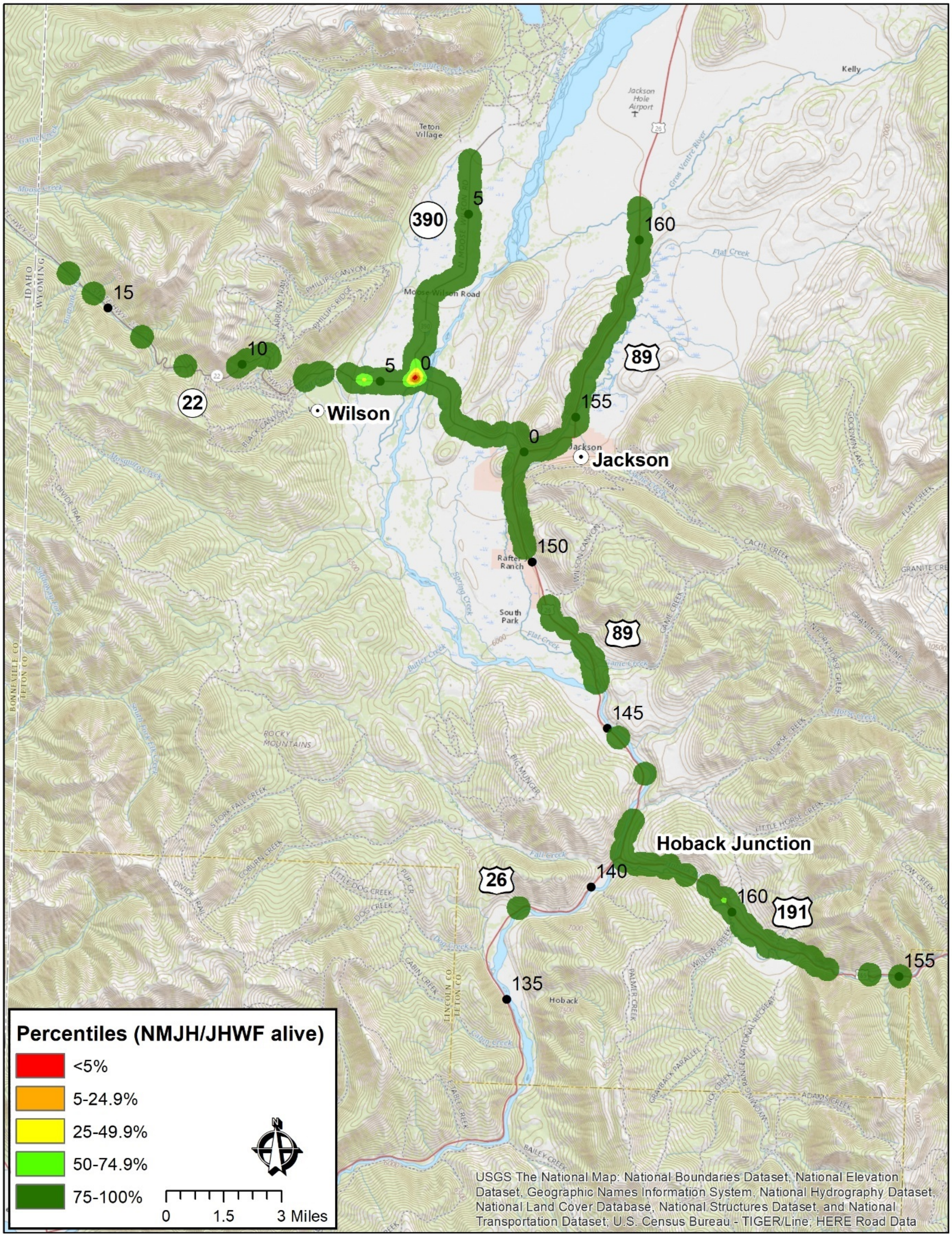
4.3. Biological Conservation

The researchers used the following publications and other sources to identify road sections where large mammals are frequently seen on or near the road or where habitat or movement corridors intersect the seven highway segments:

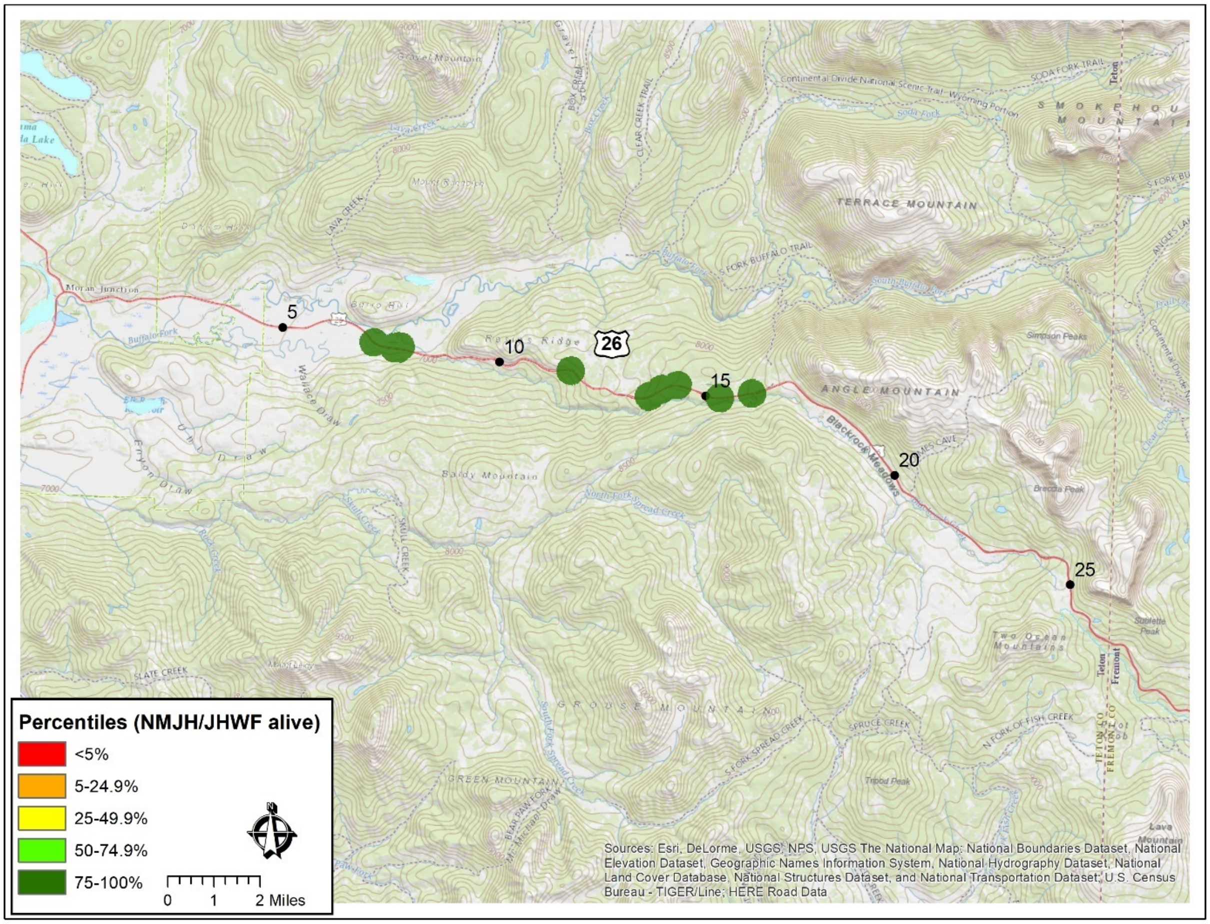
1. Nature Mapping Jackson Hole (NMJH) / Jackson Hole Wildlife Foundation (JHWF) live observation data (incidental observations by agency personnel, and by the public (Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation, 2017b). The data requested and received were limited to terrestrial wildlife species coyote size and larger within 100 m the major highways between 1 January 2006 through 31 December 2015.
2. Mule deer migration data (Riginos, 2013; 2016; Wyoming Migration Initiative, 2017; Pers. Com. Matt Kauffman, Wyoming Migration Initiative; Pers. Com. Corinna Riginos; Pers. Com. Sarah Dewey, Grand Teton National Park).

3. Elk migration data (Wyoming Migration Initiative, 2017; Pers. Com. Matt Kauffman, Wyoming Migration Initiative; Pers. Com. Ben Wise, Wyoming Game & Fish Department; Pers. Com. Corinna Riginos)
4. Moose movement observation data along the Buffalo Fork River (US Hwy 26/287) (Becker, 2008; Becker et al., 2008), supplemented by observations of alive and dead moose in Teton County (WYDOT, 2016; Hood et al., 2017; Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation, 2017b; Pers. Com. Morgan Graham, Teton Conservation District).
5. Local knowledge on the distribution of species that are considered a conservation concern (e.g. advisory group for this project).

For the Nature Mapping Jackson Hole (NMJH) / Jackson Hole Wildlife Foundation (JHWF) live observation data, the researchers considered road sections with no observations and road sections that fell into the two lowest density categories (50-100%; Table 4) (provided that the density is greater than 0) to be “background”. Road sections that had higher densities (“top 50%”) were considered a “hotspot” (i.e. yellow, orange or red in Figure 17, Appendix D).



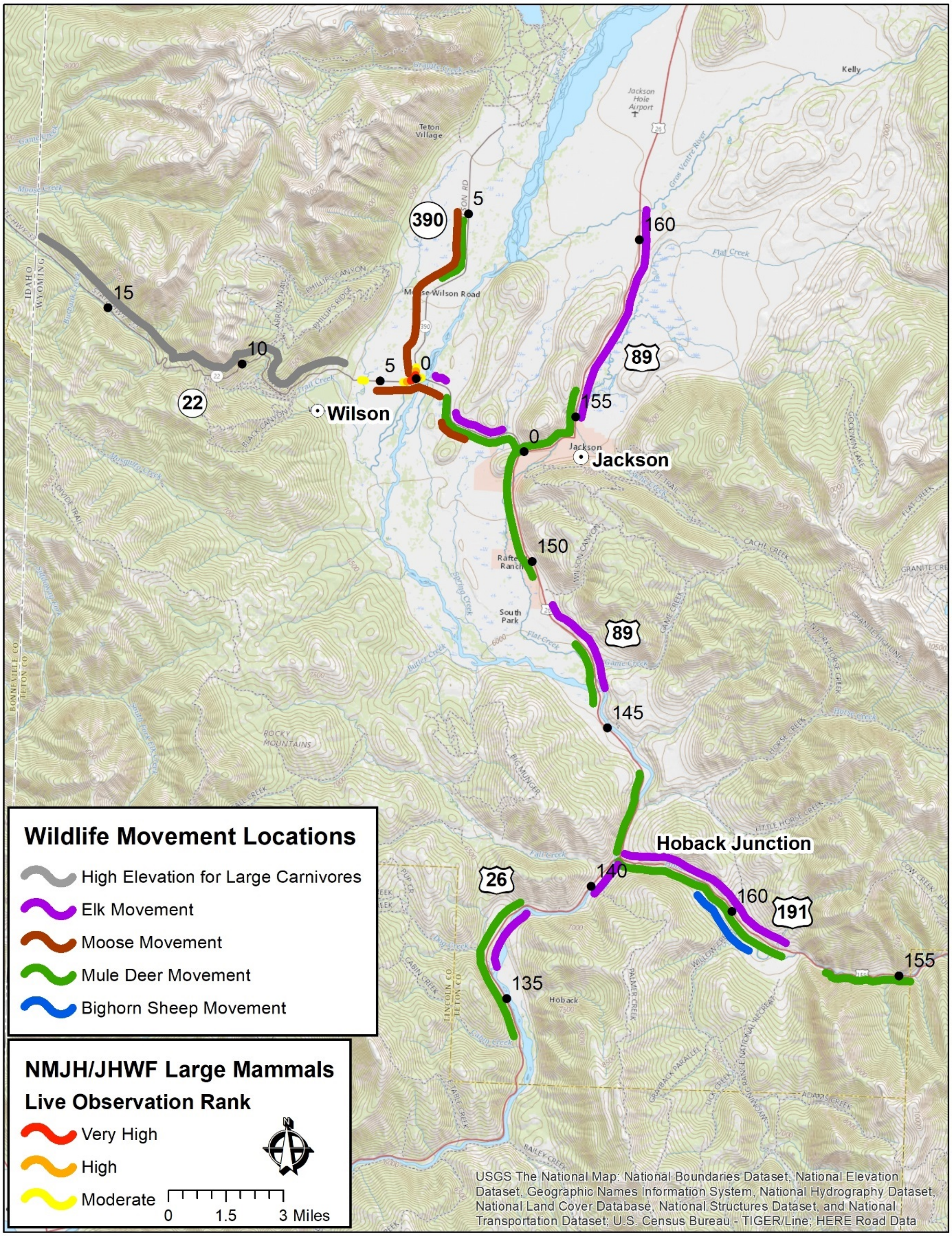
Jackson area



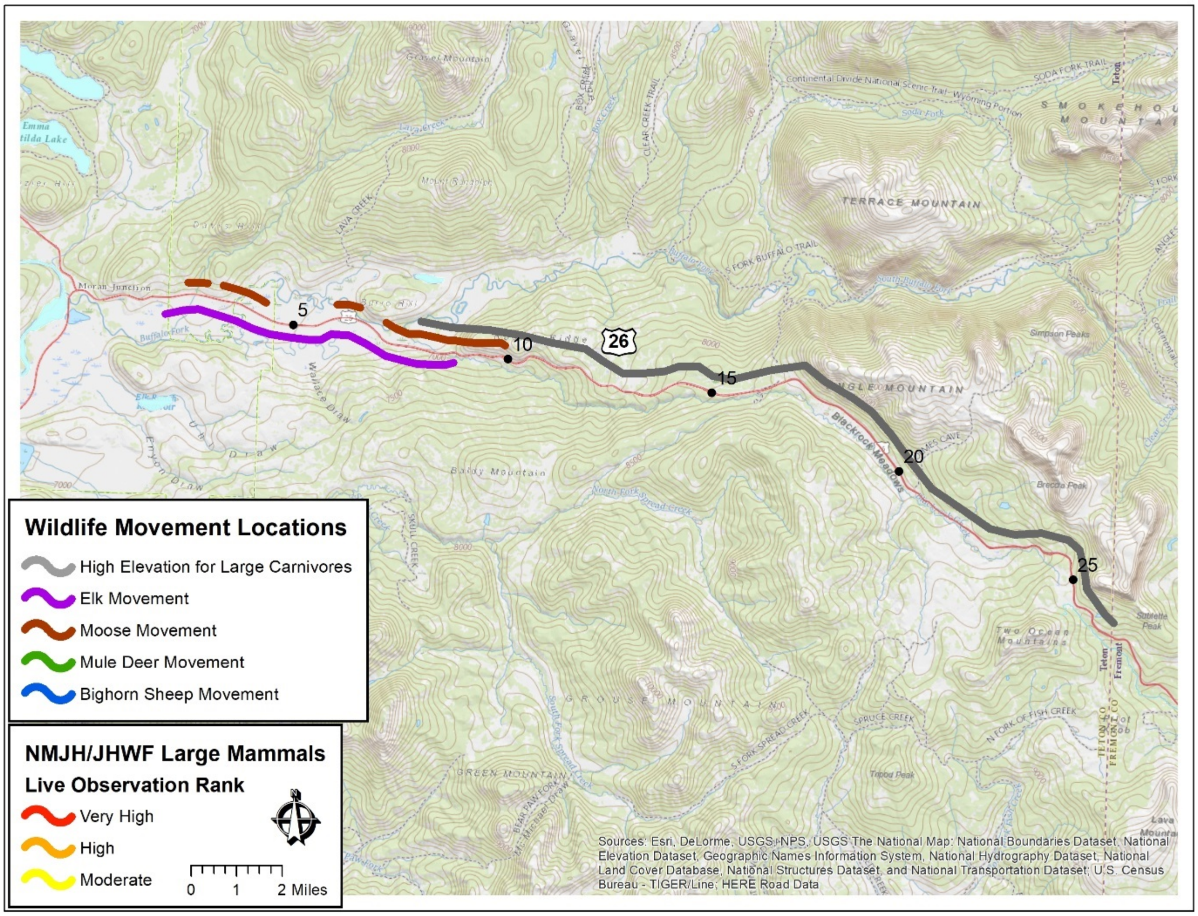
Togwotee Pass

Figure 17. Hotspots for live observations of large wildlife species on or near highways (Jackson Hole Wildlife Foundation, 2017b).

The researchers summarized the mule deer, elk, and moose migration or movement data (Figure 18). Whenever a road section crossed a migration or movement areas for one of the three species, the road section was identified in green for deer, purple for elk, and red for moose (no buffers, no margins) (Figure 18).



Jackson area



Togwotee Pass

Figure 18. Road sections known to be cutting across migratory paths or movement areas for large mammals, and deer, elk, moose, and bighorn sheep specifically.

Most of the other large mammal species that are considered a conservation concern have a low population density and are rarely hit by traffic or seen alive on and along the highways in Teton County (see section 4.2.1.). This is especially true for gray wolf (*Canis lupus*), wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*), and grizzly bear (*Ursus arctos*). Bison and pronghorn occur mostly north of the Gros Ventre river (between road section 4 and 5, in and around Grand Teton National Park). However, mitigation measures for these species are probably most appropriate along road sections in high elevation areas with low human impact (e.g. Togwotee Pass (road section 5) and Teton Pass (road section 6). The migration route “Path of the Pronghorn” does not bisect any of the seven road sections evaluated. The pronghorn migration route crosses US Hwy US Hwy 26/89/191 north of the Gros Ventre River (i.e. north of road section 4 in Figure 1) (Wyoming Migration Initiative, 2017). Bighorn sheep are known to frequent the steep terrain and adjacent road section of US Hwy 189/191 around Camp Creek (road section 1). Bison occur mostly within Grand Teton National Park. Because of the human-livestock-wildlife conflicts, the researchers were asked to not include bison in the identification or prioritization process for measures associated with this Master Plan. Measures that benefit northern river otter are most appropriate at river and stream crossings.

4.4. Land Ownership

Landownership of the land beyond the right-of-way can influence the decision process of where to mitigate and how to mitigate wildlife-vehicle collisions and provide for safe wildlife crossing opportunities. Mitigation measures such as concrete underpasses or overpasses typically cannot be moved, and if the land use on either side of a crossing structure changes and reduces (potential) wildlife use of the structure, the investment in the mitigation measure will not generate the expected benefits. Therefore, wildlife crossing structures such as overpasses and underpasses are often only constructed when the land on the other side of the highway is "secured" as wildlife habitat (e.g. state lane, federal land, or private land with a conservation easement). The researchers plotted landownership for the seven different road sections on a series of maps (Appendix E). However, in consultation with the Advisory Committee for this project, we did not exclude locations from our prioritization based on land ownership.

4.5. Cost-Benefit Analyses

Over 40 types of mitigation measures aimed at reducing collisions with large ungulates have been described (see reviews in Hedlund et al. 2004, Knapp et al. 2004, Huijser et al. 2008). Examples include warning signs that alert drivers to potential animal crossings, wildlife warning reflectors or mirrors (e.g., Reeve and Anderson 1993, Ujvári et al. 1998), wildlife fences (Clevenger et al. 2001), and animal detection systems (Huijser et al. 2006). However, the effectiveness and costs of these mitigation measures vary greatly. When the effectiveness is evaluated in relation to the costs for the mitigation measure, important insight is obtained regarding which mitigation measures may be preferred, at least from a monetary perspective.

For this report the researchers conducted cost-benefit analyses for four different types and combinations of mitigation measures. The types and combinations of mitigation measures evaluated for this report included:

- Fence, under pass (once every 2 km), jump-outs
- Fence, under- and overpass (underpass once every 2 km, overpass once every 24 km), jump-outs
- Fence, gap (once every 2 km), animal detection system in gap, jump-outs
- Animal detection system (not combined with a wildlife fence)

For details on the effectiveness and estimated costs of the mitigation measures per mile (1.609 km) per year and other methodological aspects of the cost-benefit analyses see Huijser et al. (2009). This publication also provides a rationale for the estimated costs associated with each deer-, elk-, and moose-vehicle collision. The cost for a collision is a combination of the average costs due to vehicle damage, human injury, human fatality, and lost wildlife value to hunters. Note that passive use values (e.g. the value of wildlife for tourism) were not included in these cost estimates. Should they be included, the benefits of implementing effective mitigation measures increase. The "benefit" of implementing effective mitigation measures is the collision costs that are avoided. The cost-benefit analyses were conducted over 75 years; consistent with the projected life span of concrete structures. The analyses were based on 2007 US $.

The cost for large mammal-vehicle collisions is expressed in dollars per year per mile (1.609 km). The cost estimates are based on a divided four-lane highway (two lanes in each direction) as the mitigation measures are more likely to be implemented with an overall road reconstruction that involves a wider and higher capacity highway then the implementation of mitigation measures as a stand-alone project along a two-lane road.

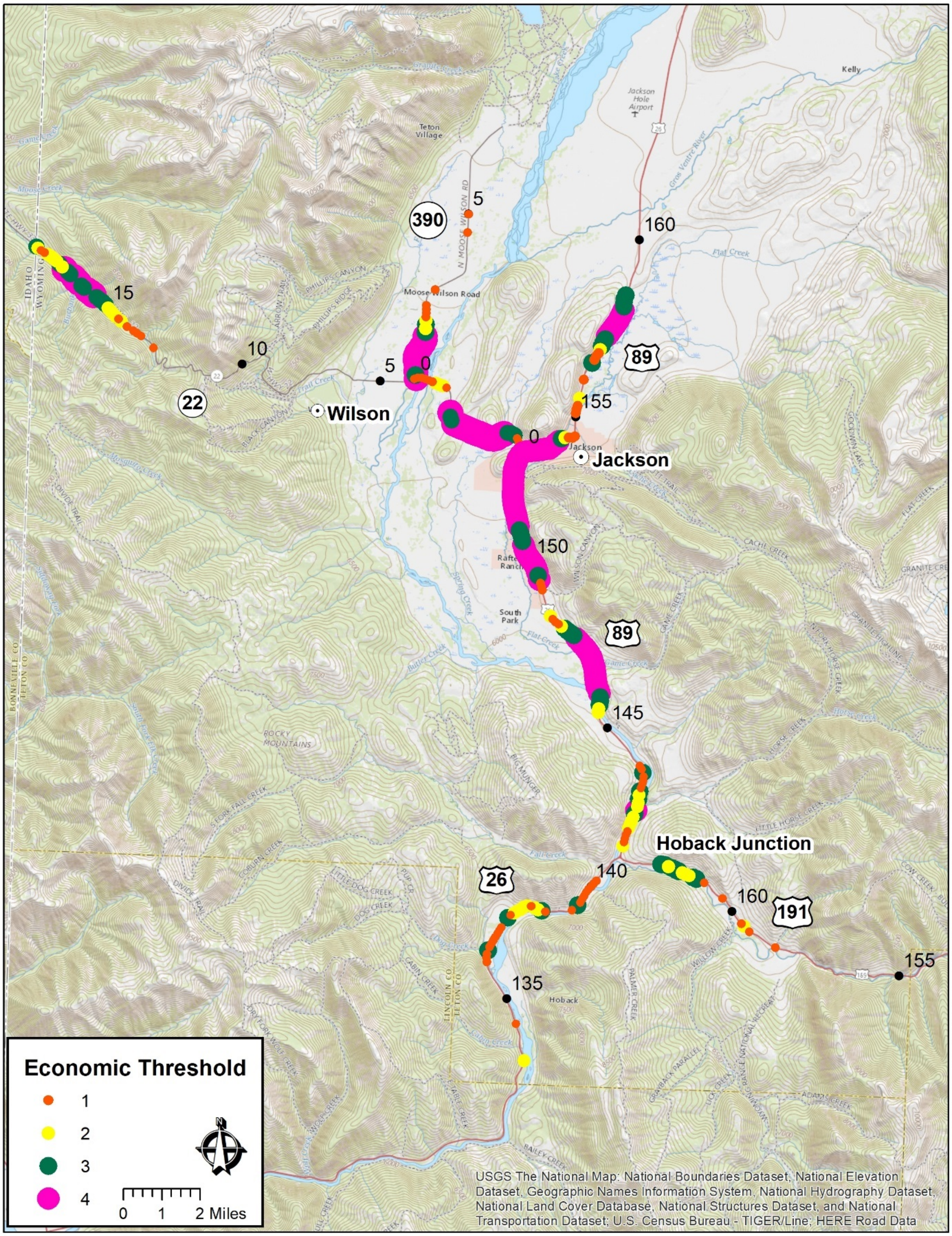
For this cost-benefit analysis, the researchers used the collision data from Jackson Hole Wildlife Foundation (2006 through 2015, combination of all known collisions from all sources). The analyses include all large wild mammal species, but for the analyses species were assigned to “deer” “elk” or “moose” based on similarity in body weight. “Deer’ included mule deer, white-tailed deer, pronghorn, bighorn sheep, mountain lion, gray wolf, black bear, and grizzly bear. “Elk” related only to elk and “moose” related to moose and bison. The costs per mile associated with large wild mammal-vehicle collisions were calculated for each 0.1 mile highway segment based on a running average for that 0.1 mile and half a mile up and half a mile down the highway (eleven 0.1 mile segments in total). This smoothened out spatial imprecision from data collectors who round off the location to the nearest 0.5 or 1.0 mile reference post.

Note that the cost-benefit model is primarily based on human safety parameters. If passive use values (e.g. wildlife viewing by tourists) were included in the cost-benefit analyses, then species with a high conservation value could have a substantial influence on the outcome of the analyses, resulting in more and longer road sections that would meet or exceed the thresholds for the four different combinations of mitigation measures. Note that the cost-benefit analyses does not include costs associated with potential land acquisition.

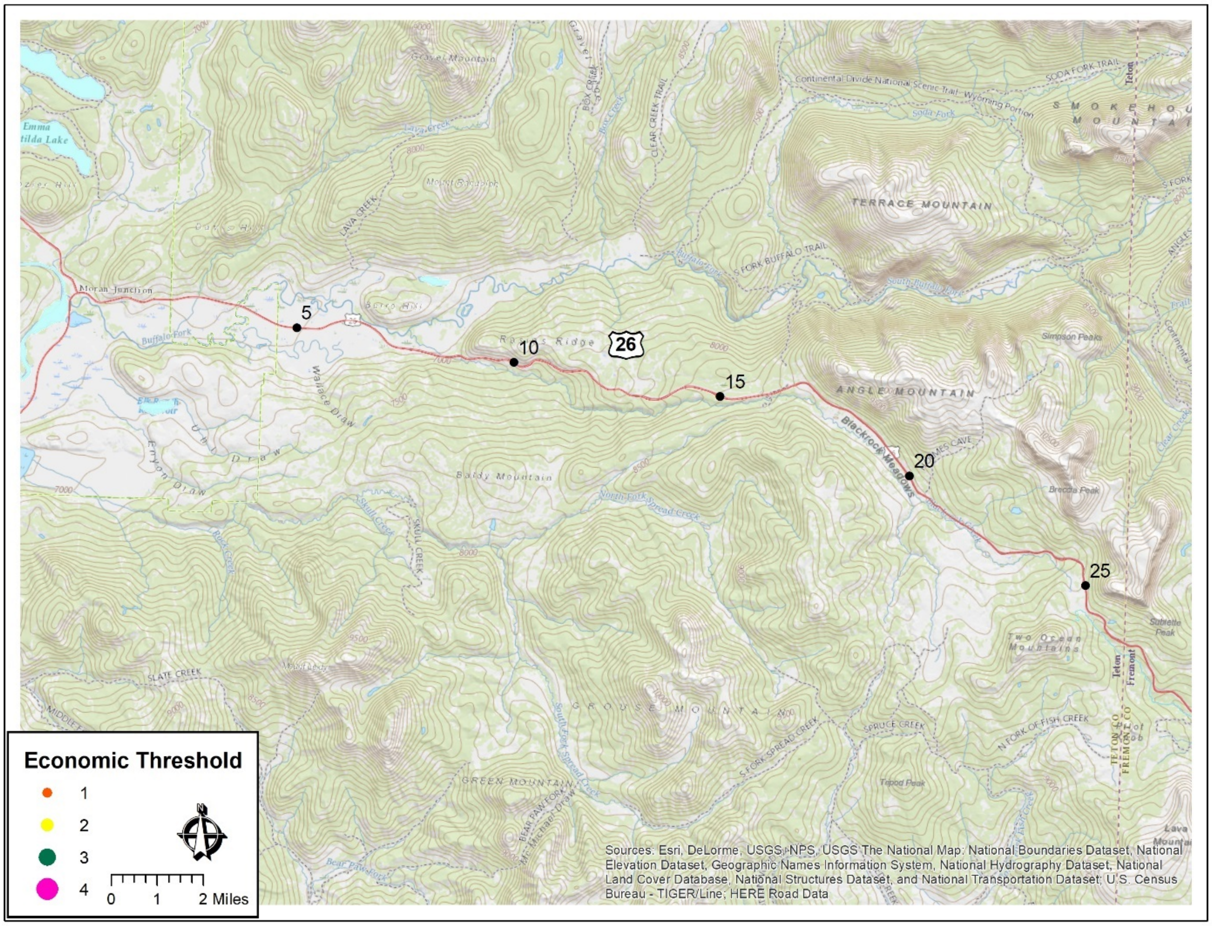
Figure 19 shows for which road sections the costs associated with large wild mammal-vehicle collisions reached or exceeded the thresholds of four different mitigation packages (the “raw data for this figure are presented in Appendix F). Note that the costs associated with animal detection systems are estimated to be higher than for underpasses or overpasses. While the initial costs for an animal detection system may be lower than for concrete structures, concrete structures have a projected life span of 75 years while animal detection systems have a projected life span of only 10 years.

The following highway sections have the highest costs associated with large wild mammal-vehicle collisions and would thus have the greatest economic benefits of implementing mitigation measures aimed at reducing collisions and providing safe crossing opportunities:

- US Hwy 26/89/191 South end South Park Loop Rd - Jackson (Broadway).
- US Hwy 26/89/191 Snake River- Game Creek area.
- US Hwy 26/89/191 near Fish Hatchery.
- WY 22: Spring Gulch - west of Bar Y Rd.
- WY 22: Jct with WY 390.
- WY 22: Between weigh station and Trail Creek Campground.
- WY 390: Jct WY 22 – Andersen Ln.



Jackson area



Togwotee Pass

Figure 19. Road sections for which the costs associated with large wild mammal-vehicle collisions reached or exceeded the thresholds of four different mitigation packages (in 2007 US$, 3% discount rate). 1 = Threshold fence, under pass, jump-outs ($29,166/mi/year), 2 = Threshold fence, under- and overpass, jump-outs ($38,994/mi/year), 3 = Threshold fence, gap, animal detection system, jump-outs ($45,303/mi/year), 4 = Threshold animal detection system ($59,568/mi/year). Note: no road sections met any thresholds on Togwotee Pass.

4.6. Prioritization

The researchers ranked the road sections for the potential implementation of mitigation measures. The ranking was based on a two-step process.

- Step 1: The calculation of a parameter based on a combination of human safety and economics, and the calculation of a parameter based on biological conservation.
- Step 2: The calculation of a final overall ranking parameter based on the two parameters calculated in Step 1.

4.6.1. Step 1: The calculation of a parameter based on a combination of human safety and economics, and the calculation of a parameter based on biological conservation.

- Parameter based on human safety and economics.

  This was based on one parameter: The costs (per mile per year) associated with collisions based on the collision data from Jackson Hole Wildlife Foundation (2006 through 2015, combination of all known collisions from all sources).

  This parameter weighted collisions of large wild mammals on body size (three size categories: similar to deer, elk, or moose) (see section 4.5; Huijser et al, 2009). This means that a moose collision had a greater weight than a deer or an elk collision. This parameter reflects human safety interests, weighted by the body size of the animal, as the body size is associated with higher economic costs and higher risk for human safety.

  Based on the cost-benefit analysis (see section 4.5), the researchers found that the highest cost per mile per year associated with wildlife-vehicle collisions was $113,660 (Hwy section 4, mile reference point 153.5). This value was set to 100%. The researchers then calculated the costs associated with large wild mammal-vehicle collisions for each 0.1 mile road segment as a percentage of the $113,660.

  The raw data for the prioritization process are in Appendix G, H, and I.

- Parameter based on biological conservation.

  This was based on wildlife observed along the highway and known corridors and habitat.

Biological conservation consisted of 6 sub-parameters:

1. “Large mammal observation data”. This sub-parameter consisted of the Nature Mapping Jackson Hole (NMJH) / Jackson Hole Wildlife Foundation (JHWF) live observation data (Figure 17). Only road sections with a high concentration were included (yellow, orange and red). Road sections with “yellow”, “orange” and “red” were all awarded 1 point. Road sections that had lower concentrations of live observations were not awarded any points.
2. Mule deer movement area. This sub-parameter consists of mule deer migration data (Figure 18). If a road section crosses a mule deer migration path or a mule deer presence area, the road section is awarded 1 point. Road sections that did not cross a mule deer migration route or presence area were not awarded any points.
3. Elk movement area. This sub-parameter consists of elk migration and elk presence data (Figure 18). If a road section crossed an elk migration path or an elk presence area, the road section was awarded 1 point. Road sections that did not cross an elk migration route or presence area were not awarded any points.
4. Moose movement area. This sub-parameter consists of moose migration and moose presence data (Figure 18). If a road section crossed an elk migration path or presence area, the road section was awarded 1 point. Road sections that did not cross a moose migration route or presence area were not awarded any points.
5. Bighorn sheep presence area. This sub-parameter consists of bighorn sheep presence data (Appendix H). If a road section crossed a bighorn sheep presence area, the road section was awarded 1 point. Road sections that did not cross a bighorn sheep presence area were not awarded any points.
6. Large carnivore presence area. This sub-parameter consists of large carnivore presence data (Appendix H). If a road section crossed a large carnivore presence area, the road section was awarded 1 point. Road sections that did not cross a large carnivore presence area were not awarded any points.

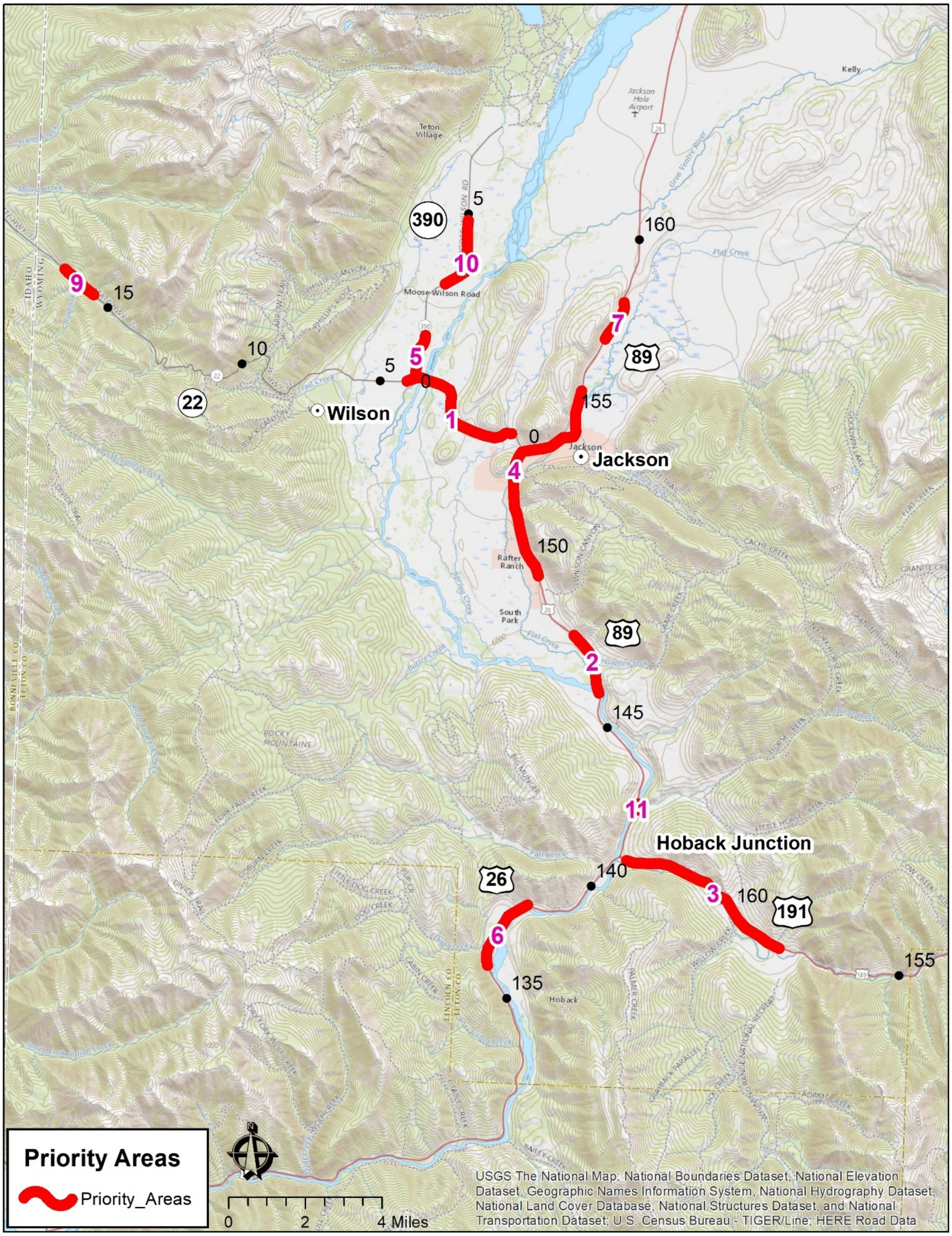
The 6 sub-parameters were combined into one biological conservation ranking parameter by summing the points for the six sub-parameters (Theoretical maximum score 6x1)=6 points). However, for the road sections evaluated for this project the actual maximum value that was reached was 3. This value (3) was set to 100%. The researchers then calculated the score for biological conservation for each 0.1 mile road segment as a percentage of the maximum score (3 points). The raw data for the prioritization process are in Appendix G, H and I.

4.6.2. Step 2: The calculation of a final overall ranking parameter based on the two parameters calculated in Step 1.

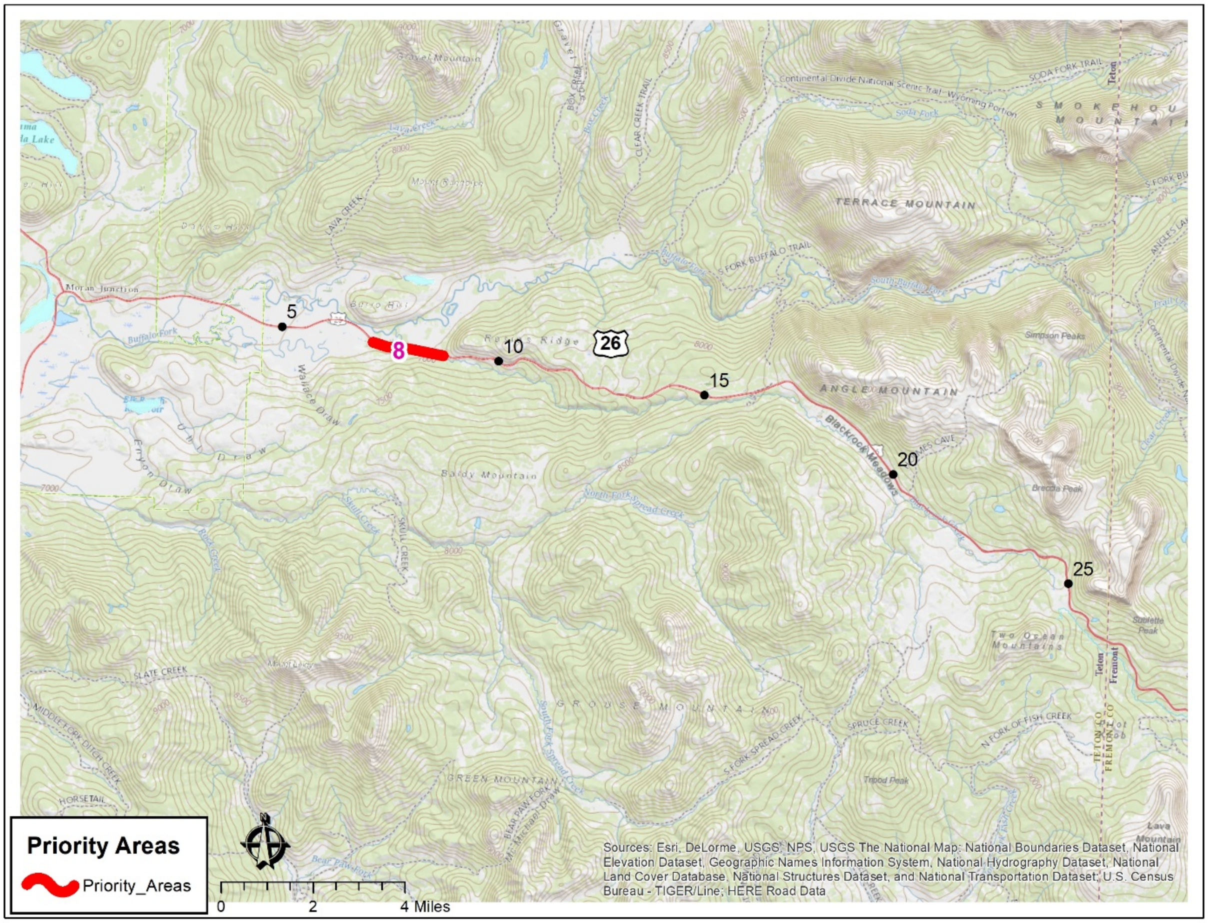
The two parameters from step 1 (human safety and economics combined and biological conservation) were weighted equally and combined into 1 final ranking parameter by adding the two percentages and dividing them by 2 (maximum score final ranking parameter is 100%) (Appendix I). Note that the actual maximum score for a 0.1 mi road section was 91.4 (section 6, mile reference post 1.8).

Road sections with ≥80-100% were marked red, ≥60-80% were marked orange, and ≥40-60% were marked yellow (Appendix I). Gaps between marked sections that were shorter than 1 mile were considered insignificant in relation to the minimum road length (3 miles) that wildlife fences should be implemented at, and they were treated as one road section (Huijser et al., 2016a; Table 5)).

The selected road sections (≥40-100%) were ranked based on the highest maximum score for an individual 0.1 mile road segment (Figure 20; Table 5). Note that the table also includes additional parameters such as the length of the road section, and the average score. The total length of the road sections that were assigned ranks was 26.4 miles (30.2%) out of the 87.5 miles that were part of the study.



Jackson area



Togwotee Pass

Figure 20. The road sections that ranked highest based on a combination of human safety and economics, and on biological conservation (see also Appendix I).

Table 5: The road sections that ranked highest based on a combination of human safety and economics, and on biological conservation (see also Appendix I).

Description road section	Hwy section	Hwy number	Start m reference post	End mi reference post	Length (mi)	Maximum final ranking (%)	Average final ranking (%)	Rank	North or west side	East or south side	Target species
Spring Gulch - Jct WY 390	6	22	0.6	4.3	3.8	91.40	55.46	1	P, PE	P	Mule deer, elk, moose
Snake River - Game Creek area	3	S 89	146.0	147.7	1.8	82.73	67.64	2	P, WYGFD	P, WYGFD FS	Mule deer, elk
Camp Creek area - Hoback Jct	1	191	158.4	163.3	5.0	69.13	53.56	3	P, FS, PE	P, FS	Mule deer, elk, bighorn sheep
South Park Loop (south end) - Jackson	3/4	S/N 89	149.6	155.7	6.2	66.67	47.63	4	P, TC	P, FS	Mule deer, elk
Jct Hwy 22 - N Lily Lake Lane	7	390	0.0	1.2	1.3	63.43	51.63	5	PE	BLM, P	Moose
Dog Creek - Hoback elk feed ground area	2	26	136.0	138.0	2.1	55.09	49.28	6	FS, P	FS, P, PE	Mule deer, elk
Fish Hatchery	4	N 89	157.2	158.3	1.2	53.17	45.50	7	NER, P, PE	NER, P	Mule deer, elk
Blackrock Ranger Station area	5	26	7.2	8.8	1.7	53.16	45.35	8	FS, P	FS, P	Moose, Elk, Large carnivores
Weigh Station area	6	22	15.5	16.5	1.1	49.64	43.91	9	FS	FS	Moose, Large carnivores
Wilderness Dr - Snake River Ranch Rd	7	390	2.8	4.8	2.1	47.63	43.22	10	P, TC	P, PE	Mule deer, moose
Horse Creek area	3	S 89	142.5	142.5	0.1	43.88	43.88	11	FS	FS	Mule deer, elk
Total					26.4						

Legend

BLM	Bureau of Land Management
FS	Forest Service
NER	National Elk Refuge
P	Private
PE	Private with conservation Easement
TC	Teton County
WYGFD	Wyoming Game & Fish Department

4.6.3. Considerations

While the prioritization of the road sections can be useful, the researchers would like to point out the following:

1. The final ranking is based on a combination of human safety and the costs associated with collisions, and on biological conservation.
2. The results of the prioritization process can be used to identify road sections where mitigation measures would have the most benefit for human safety, biological conservation, and economics. However, it is also advisable to have a parallel, more opportunistic approach. Wildlife mitigation measures can also be implemented when a road section is reconstructed because of human safety issues (all types of crashes, especially those that also result in human injuries and human fatalities), physical problems with the road surface or the road bed, or traffic volumes that are considered too high for the road configuration. It is typically less expensive and less disruptive to traffic flow to implement wildlife mitigation measures at the same time a road section is reconstructed in its entirety, and it may be multiple decades before the same road section is reconstructed again, and another opportunity presents itself.
3. The weighting of the different biological conservation parameters is subjective, and one may change the weighting procedure should one choose to do so. The data required for a different weighting process are included in Appendix G, H and I. Similarly, the equal weight given to human safety and economics vs. biological conservation, is also a choice.
4. Just because certain road sections did not rank high in the prioritization process, it does not mean that mitigation measures in those road sections are not critical. For example, if a road section has few collisions with common large ungulates, it is not possible for that road section to rank high in the prioritization process. However, that same road section may cut across a migratory path or important habitat for one or more wildlife species, and reducing the barrier effect of the transportation corridor may be critical for the preservation of seasonal migration or the long-term population viability for these species.
5. Addressing wildlife-vehicle collisions and habitat connectivity issues along the road sections that ranked highest in the prioritization process does not necessarily mean that all or most wildlife-vehicle collisions have been eliminated, nor does it mean that all or most wildlife connectivity issues have been addressed. It only means that the locations

that ranked highest based on a combination of human safety and economics, and biological conservation have been addressed.

6. Addressing unnatural mortality (here direct road mortality) and barriers in the landscape (here highways and traffic) for individual species that have a biological conservation concern, requires a species-specific approach in the wider region. The outcome of such species-specific analyses in a wider region may result in different priorities for mitigation sites.
7. The prioritization process did not include landownership adjacent to the transportation corridors. However, the long-term security of the lands on either side of safe wildlife crossing opportunities and their functioning as wildlife habitat and wildlife corridor, is critical to the long-term benefits of the crossing opportunities. The researchers suggest exploring whether habitat and corridors adjacent to the highways can be safe guarded for the future rather than never considering mitigating road sections adjacent to land that may be developed and that may become less suitable or unsuitable for wildlife in the future.

5. IDENTIFY AND PRIORITIZE POTENTIAL MITIGATION SITES FOR STREAM CROSSINGS

5.1. Introduction

Teton County has a diversity of aquatic habitats including large rivers such as the Snake and Gros Ventre Rivers and many small- to medium-sized streams and rivers. The road system crosses a number of these and uses hydraulic structures ranging from large bridges, such as those over the Snake River, to smaller structures typically constructed of single span bridges, or single- to multi-barrel culvert batteries. For the remainder of this chapter, road-stream crossings will be used as a general term for all hydraulic structures crossing aquatic habitats.

5.2. Scope and Purpose

Our team was tasked with providing “high-level” general design recommendations for replacing existing stream crossings with new structures. To develop them, we performed the following tasks:

- We reached out to key stakeholders to gather existing information about road-stream crossing structures in Teton County, the aquatic habitats they cross, hydrology and geomorphology of the counties’ rivers and streams, and fisheries.
- Along with members of the Advisory Group and key stakeholders, we visited a range of different road-stream crossings to gain a better understanding of site-specific and regional issues, and to get a clearer idea of the physical and biological setting.
- We developed general or “high-level” mitigation measures or strategies with a focus on providing long-term aquatic connectivity moving forward.
- And, we integrated mitigation strategies for terrestrial and semi-aquatic wildlife at stream crossings (e.g. riparian and terrestrial habitat). This integration was very important as one structure can address the barrier effect of a road and associated traffic for both aquatic and terrestrial species.
- The scope of the aquatic’s work did not include collection of any new information or development of any prioritization strategies for replacement of existing road-stream crossings.

This chapter starts with a summary of existing road-stream crossings in Teton county, describes the site visits performed in May 2017 and key observations from them, presents the recommended mitigation measures or strategies for replacement of road-stream crossings, and ends with a recommendation for development of a prioritization to evaluate and replace road-stream crossings in the future.

5.3. Existing Road-Stream Crossings and Related Information

Road-stream crossings in Teton County include large bridges to span rivers such as the Snake and Gros Ventre River all the way to single-barrel corrugated metal pipe culvert structures. Many of the road-stream crossings use single or double concrete box culverts to pass water underneath the roads. Concrete box structures are a common type of road-stream crossing in Teton County and across the country partly because they come in a large range of sizes, and are strong, thus providing long-term structure stability and integrity of the road for traffic and safety. A total of 70 road-stream crossings were identified on the road system managed by Teton County and Wyoming Department of Transportation and included in this project. This number does not include all of the road-stream crossings in the County as some are owned and operated by other regional, state or federal agencies, or are private crossings. Figures 21, 22, and 23 show examples of typical road-stream crossings in Teton County.

Figure 21. A multi-barrel crossing (site 65 along Stateline Rd, Teton Creek). View from downstream left-bank of the stream.

Figure 22. A box culvert (US Hwy 26.89, Cabin Creek).

Figure 23. A bridge (WY 22, Snake River, west bank).

Table 6 provides a summary of the road-stream crossings including the name of the waterbody crossed, the road name, whether the road-stream crossing is a bridge or culvert, and whether the habitat is considered suitable or unsuitable for fish. State fisheries biologists provided the habitat suitability parameter. Figure 24 provides an overview of road-stream crossing locations and includes the area of detail shown on Figures 25 through 28.

Table 6: Summary of Basic Road-Stream Crossing Information.

Site ID Number[1]	Road Name	Stream Name	Structure Type (Bridge or Culvert)	Habitat Suitability for Fish (Suitable/Unsuitable)
58	WILSON - FALL CREEK ROAD	Fall Creek	ND	Suitable
4	HWY 89 S	Flat Creek	Bridge	Suitable
5	TRIBAL TRAIL RD	Spring Creek	Bridge	Suitable
9	HWY 89 S	Snake River	Bridge	Suitable
11	HWY 89 S	Snake River	Bridge	Suitable
12	HWY 89 S	Flat Creek	Bridge	Suitable
13	HWY 89 N	Gros Ventre River	Bridge	Suitable
15	HOBACK JUNCTION SOUTH RD	Hoback River	Bridge	Suitable
17	FISH CREEK RD	Fish Creek	Bridge	Suitable
18	FISH CREEK RD	Fish Creek	Bridge	Suitable
21	MAIN ST	Fish Creek	Timber Bridge	Suitable
22	HWY 287	Blackrock Creek	Bridge	Suitable
23	HWY 191 S	Hoback River	Bridge	Suitable
24	HWY 191 S	Hoback River	Bridge	Suitable
27	HWY 22	Fish Creek	Bridge	Suitable
28	TETON VILLAGE RD	Fish Creek	Bridge	Suitable
30	HWY 22	Snake River	Bridge	Suitable
32	SWINGING BRIDGE RD	Snake River	Bridge	Suitable
33	BUFFALO VALLEY RD	Buffalo Fork	Bridge	Suitable
39	SOUTH PARK LOOP RD	Flat Creek	Bridge	Suitable
41	BROADWAY AVE W	Flat Creek	Bridge	Suitable
44	HWY 191 S	Hoback River	Bridge	Suitable

47	SPRING GULCH RD	Gros Ventre River	Bridge	Suitable
51	HWY 89 S	Snake River	Bridge	Suitable
63	HWY 89 N	Lava Creek	Bridge	Suitable
64	HWY 287	Buffalo Fork	Bridge	Suitable
65	STATE LINE RD S	Teton Creek	Bridge	Suitable
7	FALL CREEK RD S	Mosquito Creek	Bridge	Suitable
10	HWY 89 S	Game Creek	Single Box Culvert	Suitable
16	SPRING GULCH RD	Spring Creek	ND	Suitable
19	HENRY'S RD	Porcupine Creek	ND	Suitable
26	FALL CREEK RD N	Trail Creek	Single Arch CMP	Suitable
34	ELK REFUGE RD	Sheep Creek	ND	Suitable
45	FALL CREEK RD S	Butler Creek	ND	Suitable
46	FALL CREEK RD S	Taylor Creek	Single Box Culvert	Suitable
48	SPRING GULCH RD	Spring Creek	ND	Suitable
52	HWY 22	Coal Creek	ND	Suitable
56	WILSON - FALL CREEK ROAD	Rock Creek	ND	Suitable
57	WILSON - FALL CREEK ROAD	Pritchard Creek	ND	Suitable
60	HWY 89 S	Pritchard Creek	Single Box Culvert	Suitable
3	HWY 22	Spring Creek	Twin Box Culverts	Suitable
29	EMILY STEVENS PARK RD	Crane Creek	Culvert	Suitable
31	HWY 22	Crane Creek	Culvert	Suitable
35	BOYLES HILL RD	Cody Creek	Culvert	Suitable
36	BOYLES HILL RD	Spring Creek	Culvert	Suitable
37	BOYLES HILL RD	Cody Creek	Culvert	Suitable
38	BOYLES HILL RD	Crane Creek	Culvert	Suitable
49	HWY 22	Edmiston Spring	Culvert	Suitable
55	GAME CREEK 304550	Game Creek	Culvert	Suitable
8	HWY 89 S	Horse Creek	Large Box Culvert	Suitable
50	HWY 89 S	Fall Creek	Large Concrete Arch Pipe	Suitable

59	HWY 89 S	Cabin Creek	Concrete Box with Baffles	Suitable
62	HWY 287	Blackrock Creek	ND	ND
6	FALL CREEK RD S	Cottonwood Creek	ND	Unsuitable
14	HOBACK JUNCTION SOUTH RD	Palmer Creek	ND	Unsuitable
20	HENRY'S RD	Squaw Creek	ND	Unsuitable
25	HWY 191 S	Poison Creek	ND	Unsuitable
42	HOBACK JUNCTION SOUTH RD	Deer Creek	ND	Unsuitable
43	HWY 191 S	Camp Creek	ND	Unsuitable
53	HWY 22	Hungry Creek	ND	Unsuitable
54	HWY 22	North Fork Trail Creek	ND	Unsuitable
61	BUFFALO VALLEY RD	Box Creek	ND	Unsuitable
66	STATE LINE RD N	Dry Creek	ND	Unsuitable
67	STATE LINE RD S	Hill Creek	ND	Unsuitable
68	STATE LINE RD S	Rapid Creek	ND	Unsuitable
69	STATE LINE RD S	Spring Creek	ND	Unsuitable
70	STATE LINE RD S	Slocum Creek	ND	Unsuitable
40	ALTA NORTH RD	Dry Creek	ND	Unsuitable
1	MOOSE-WILSON RD	Lake Creek	ND	ND
2	MOOSE-WILSON RD	Granite Creek	ND	ND

Table Notes:
ND – no data
1 – Site ID number matches numbers on road-stream crossing figures.

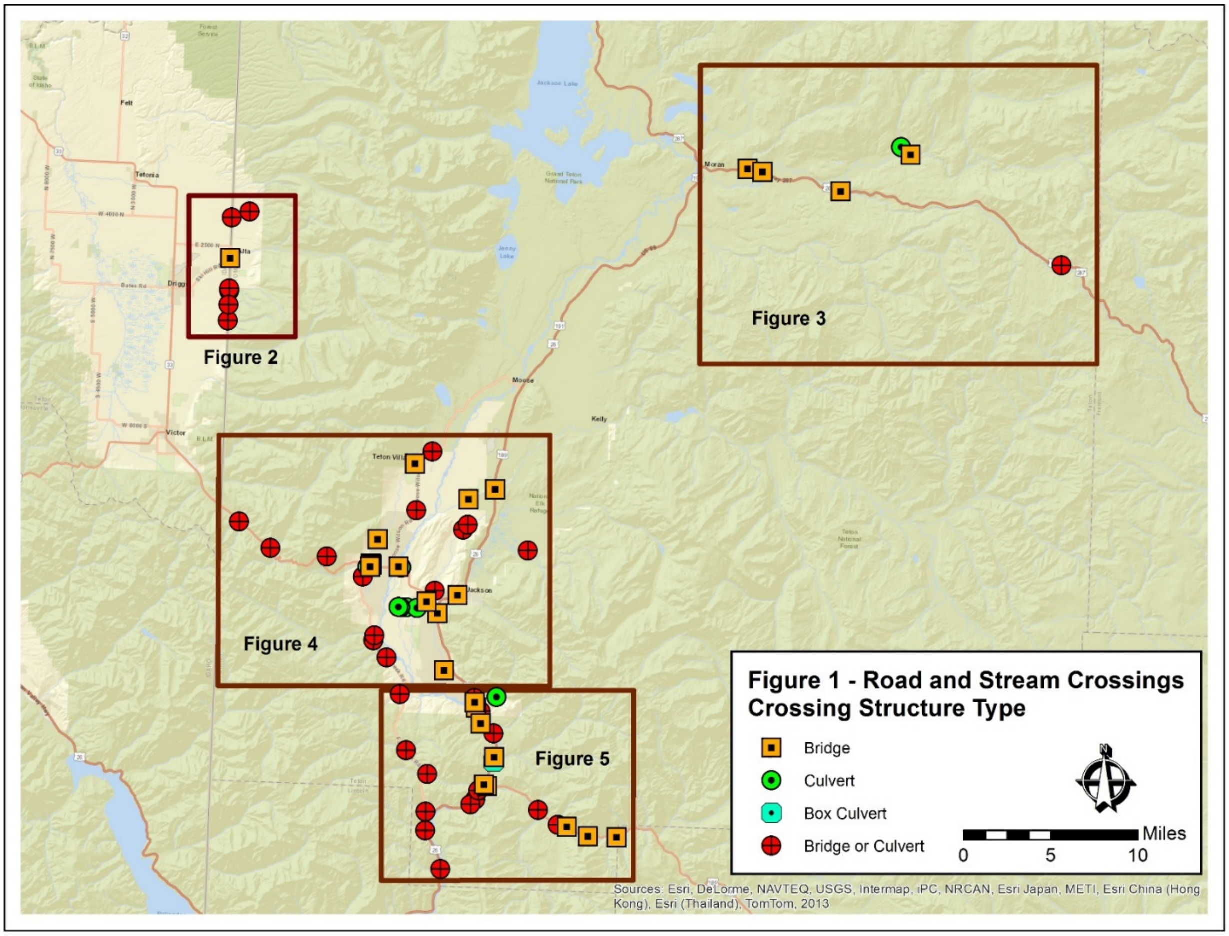


Figure 24. Overview of the stream crossings in Teton County.

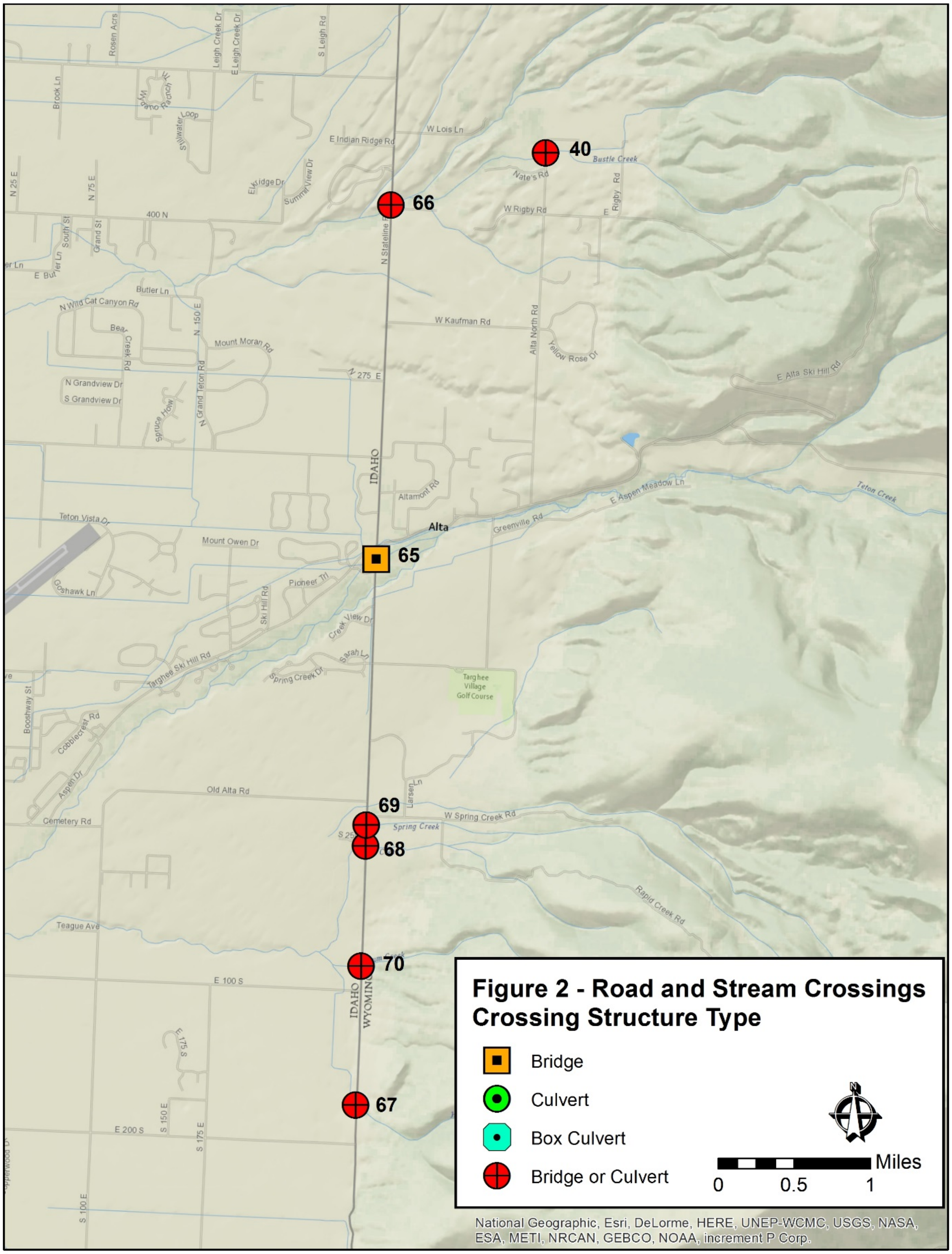


Figure 25. Zoomed in overview of the stream crossings in a part Teton County (see Figure 24 for overview).

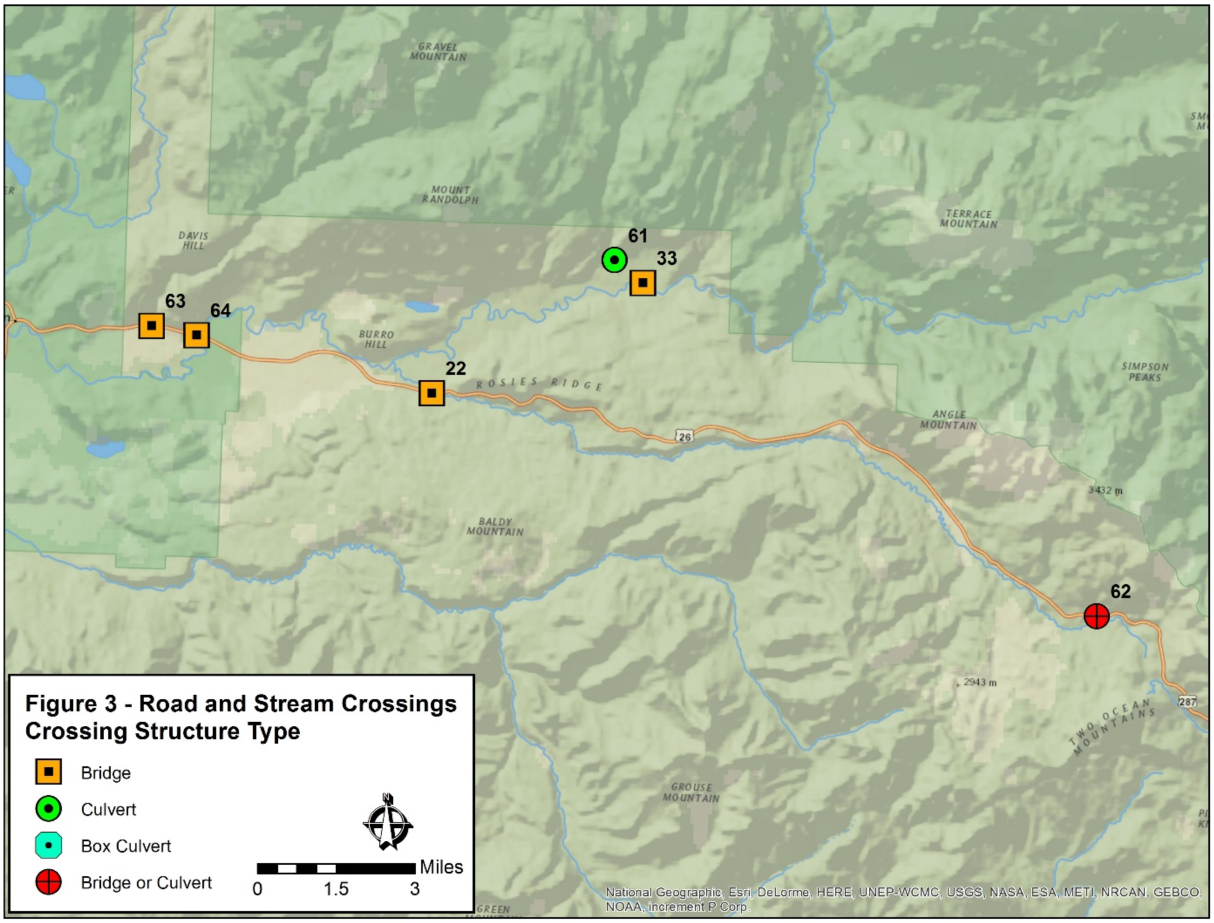


Figure 26. Zoomed in overview of the stream crossings in a part Teton County (see Figure 24 for overview).

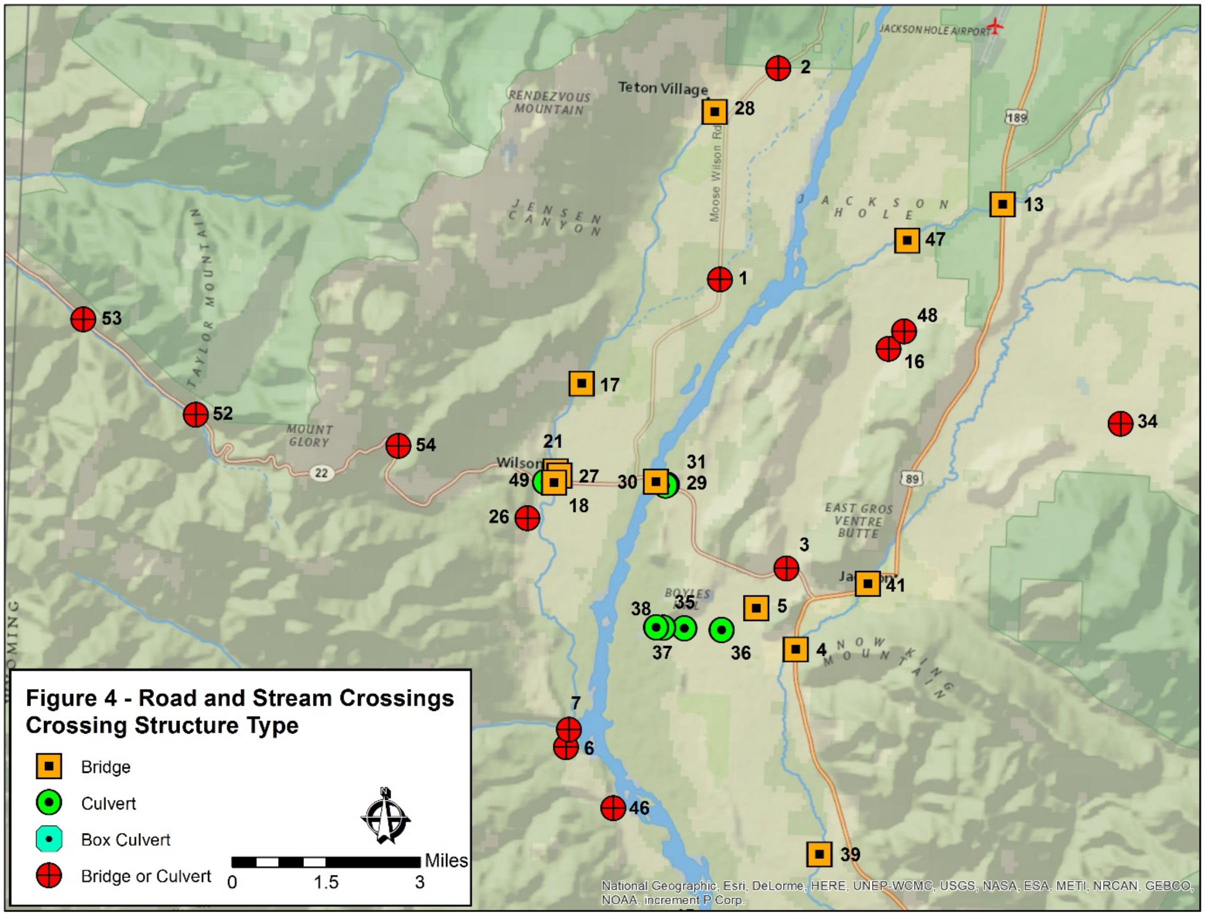


Figure 27. Zoomed in overview of the stream crossings in a part Teton County (see Figure 24 for overview).

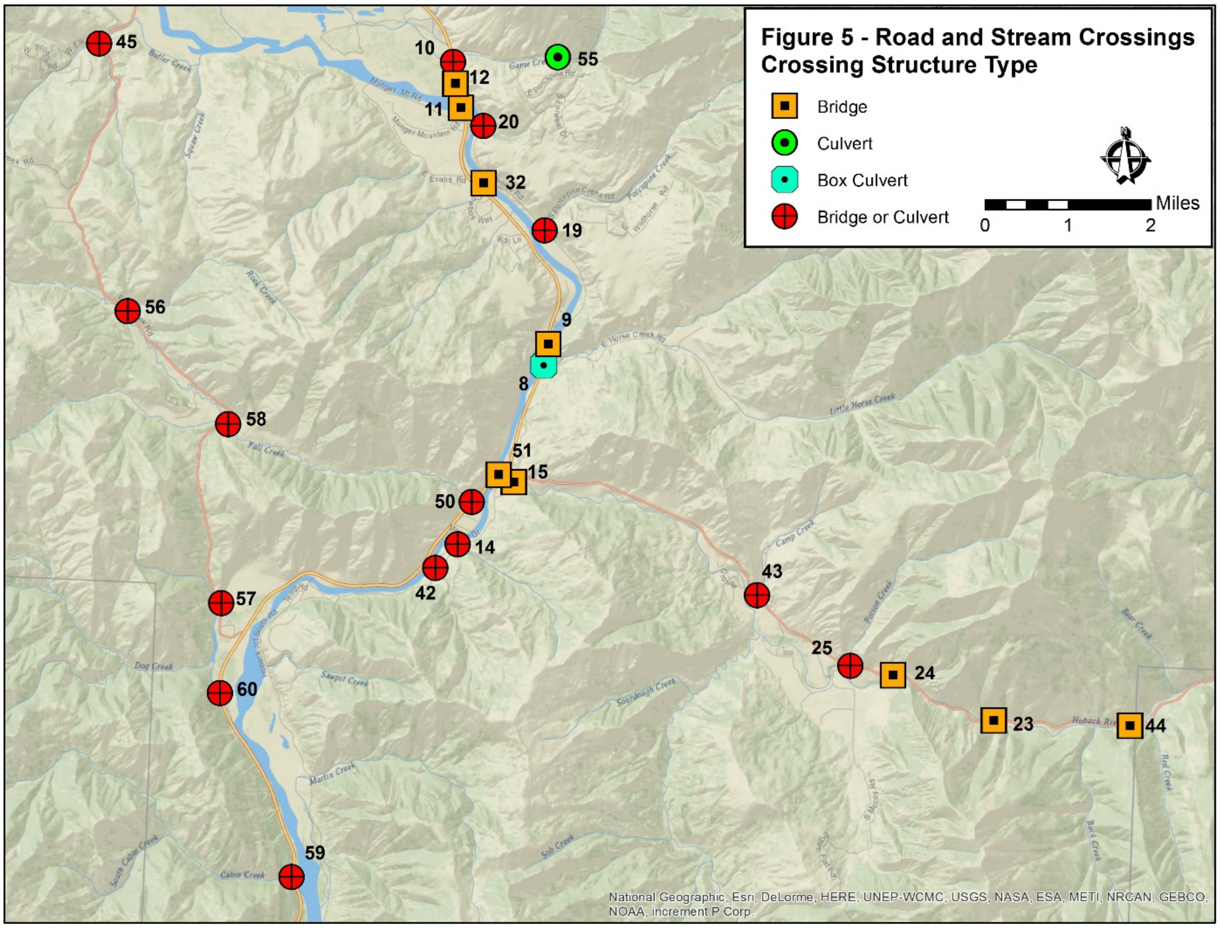


Figure 28. Zoomed in overview of the stream crossings in a part Teton County (see Figure 24 for overview).

Teton County hydrology is typical of the Northern Rocky Mountains with peak flows occurring in late spring or early summer. Figure 29 below is the 2017 hydrograph for the Snake River and is shown as an example of river or stream flows in this region. Peak flows and their timing in Teton County are driven by runoff from snowmelt. Throughout the summer and fall, high intensity and short duration thunderstorms can temporarily elevate stream flows. And, in some cases, these thunderstorms can create large flows in small drainages. Base flows generally occur from December into early April.

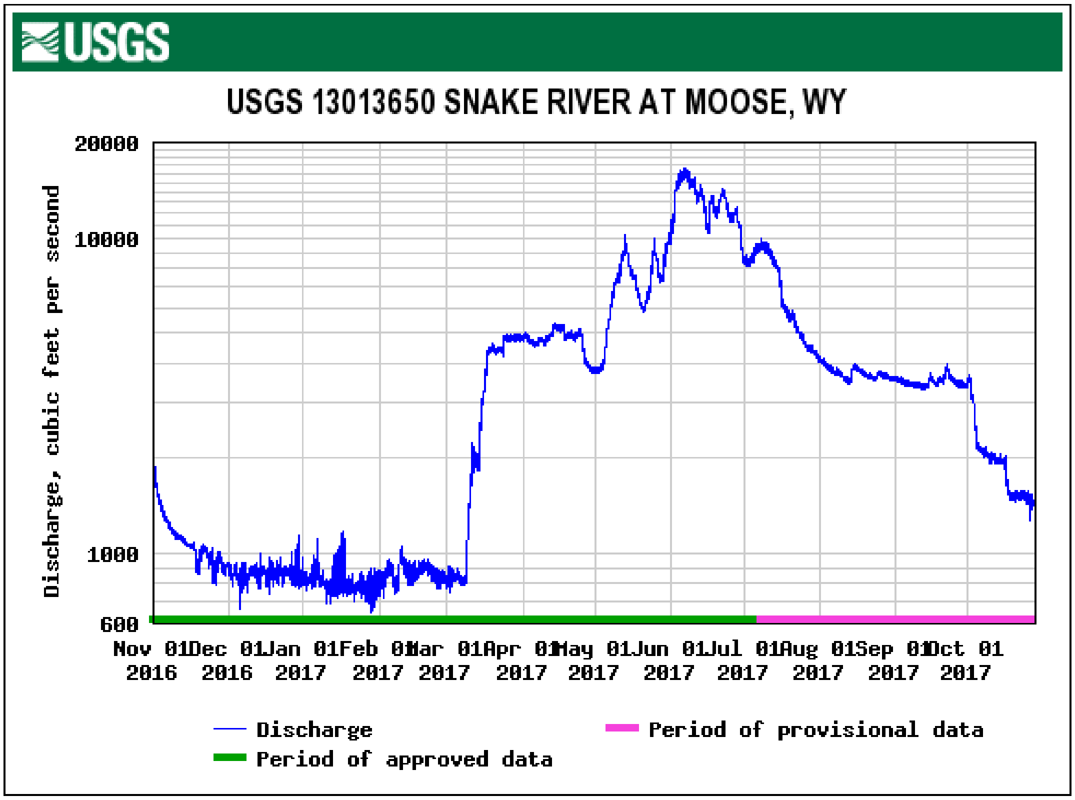


Figure 29. 2017 hydrograph for the Snake River at Moose, Wyoming. Graph downloaded from https://waterdata.usgs.gov/wy/nwis/rt on October 28, 2017.

Many streams and rivers throughout Teton County are medium- to high-gradient as they drain the nearby mountain ranges. The valley bottom has a larger variety of stream types, and does include lower gradient, more sinuous streams, some of which are spring fed. Most of the streams in Teton County are classified as perennial, meaning they have flowing water all year. There are relatively few natural lakes of large size in Teton County, thus most of the aquatic habitats and connectivity issues arise from road-stream crossings.

The Final Upper Snake River Level 1 Watershed Study classified river and stream channels in the Upper Snake River basin using the Rosgen Classification system (Olson Associates, 2016), and this data provides a good summary of the type of streams and their morphology common to Teton County. The Rosgen system is a very common way to categorize stream channel morphology. The majority of stream channels were classified as A, B, C or D channels, with percentages of 15%, 30%, 29% and 18%, respectively. An “A” channel is described as steep, entrenched, cascading, and step/pool. A “B” channel is moderately entrenched, moderate gradient, and riffle dominated. A “C” channel is low gradient, meandering, point-bars, and riffle-pool. A “D” channel is braided with longitudinal and transverse bars.

Teton County is home to both native and non-native fishes as well as several native amphibians. Table 7 summarizes both fish and amphibian species known to inhabit the Snake River drainage, and indicates whether they are native or non-native. Key species include Snake River Cutthroat

Trout and connectivity concerns in many streams and rivers are focused on maintaining high-quality habitat and native cutthroat populations. The aquatic ecosystem in Teton County is still relatively intact. Though non-native species are present, the Snake River cutthroat trout still dominate in their native range. Most fish species move throughout their ranges over their lifetimes; therefore, providing unimpeded connectivity is very important to maintain access to habitats and viable fish populations.

Table 7: Summary of native and non-native fish, and amphibians.

	Common Name	Scientific Name	Native or Non-Native
Fish	Bluehead Sucker	Catostomus discobolus	Native
	Longnose Dace	Rhinichthys cataractae	Native
	Northern Leatherside	Lepidomeda copei	Native
	Mottled Sculpin	Cottus bairdii	Native
	Mountain Sucker	Catostomus platyrhunchus	Native
	Mountain Whitefish	Prosopium williamsoni	Native
	Paiute Sculpin	Cottus beldingii	Native
	Redside Shiner	Richardsonius balteatus	Native
	Speckled Dace	Rhinichthys osculus	Native
	Snake River Cutthroat Trout	Oncorhynchus clarkii ssp.	Native
	Utah Chub	Gila atraria	Native
	Utah Sucker	Catostomus ardens	Native
	Yellowstone Cutthroat Trout	Oncorhynchus clarkii bouvieri	Native
	Brook Trout	Salvelinus fontinalis	Non-Native
	Brown Trout	Salmo trutta	Non-Native
	Fathead Minnow	Pimephales promelas	Non-Native
	Golden Trout	Oncorhynchus aquabonita	Non-Native
	Grayling	Thymallus arcticus	Non-Native
	Kokanee	Oncorhynchus nerka	Non-Native
	Lake Trout	Salvelinus namaycush	Non-Native
	Rainbow Trout	Oncorhynchus mykiss	Non-Native
Amphibians	Boreal Chorus Frog	Pseudacris maculata	Native
	Boreal Toad	Bufo boreas boreas	Native
	Columbia Spotted Frog	Rana luteiventris	Native
	Northern Leopard Frog	Rana pipiens	Native
	Tiger Salamandar	Ambystoma tigrinum	Native

5.4. Site Visits

WTI researchers and stakeholders including representatives from the Teton County Conservation District, Wyoming Department of Transportation, Teton County, Jackson Hole Conservation Alliance, and Trout Unlimited visited road-stream crossings across the county on May 12, 2017. Sites were selected based on two objectives: (1) to visit a range of different streams and rivers to capture the variety of different stream and river types, as well as road-stream crossings, in the county, and (2) to observe road-stream crossings identified as potentially having either habitat connectivity or fish passage concerns.

Observations at each crossing were split into three main groups:

(1) Operation and Maintenance. Operation and maintenance concerns included qualitative evaluation of the physical condition of the structure (s) inlet and outlet, evidence of road embankment erosion, and excessive or unnatural sediment deposition in the river or stream channel or within the crossing structure.

(2) Fish passage observations included qualitative evaluation of inlet and outlet water depths, water velocity, presence or absence of outlet drops, debris or sediment blockage and structural issues that could impede passage. These observations collectively were used to gage the effectiveness of the existing road-stream crossing in terms of river or stream continuity and aquatic connectivity.

(3) Geomorphic or Aquatic Connectivity. For this part, each crossing was evaluated in terms of how well it provided connectivity on a landscape scale, river and floodplain scale, and crossing scale.

Table 8 includes the site number and name, and initial observations of O&M, fish passage and geomorphic connectivity

Table 8: Summary of observations from May 12, 2017 field visits.

				Observations		
Site ID Number[1]	**Road Name**	**Stream Name**	**Structure Type (Bridge or Culvert)**	**O&M**	**Fish Passage**	**Aquatic Connectivity**
21	MAIN ST	Fish Creek	Timber Bridge	Appeared to be operating fine. No concern.	No concern.	Overall adequate. The bridge has little freeboard, so large woody debris could collect during large flows.
7	FALL CREEK RD S	Mosquito Creek	Bridge	Appeared to be operating fine. No concern.	There was some woody debris collecting on culverts. Could present an issue if larger amounts accumulate.	No natural banklines through culvert. Some restriction of floodplain and channel function.
10	HWY 89 S	Game Creek	Single Box Culvert	Appeared to be operating fine. No concern.	Insufficient water depths for passage. Elevated water velocities could create passage problems. Some debris accumulation. NOTE: This crossing is scheduled for replacement.	No natural banklines through culvert. Crossing restricts floodplain and channel function.
26	FALL CREEK RD N	Trail Creek	Single Arch CMP	Appeared to be operating fine. No concern.	Water velocity was elevated at time of site visit. Elevated velocity could create passage problems.	No natural banklines through culvert. Some restriction of floodplain and channel function.
46	FALL CREEK RD S	Taylor Creek	Single Box Culvert	Appeared to be operating fine. No concern.	Water velocity was elevated at time of site visit. Elevated velocity could create passage problems.	No natural banklines through culvert. Some restriction of floodplain and channel function.
3	HWY 22	Spring Creek	Twin Box Culverts	Appeared to be operating fine. No concern.	Water depth may be a concern as flows decrease. Overall, little concern for fish passage impedance.	Overall adequate. Culvert creates minor restriction of channel morhology.
8	HWY 89 S	Horse Creek	Large Box Culvert	Appeared to be operating fine. No concern.	Elevated water velocities could create passage problems. NOTE: This crossing is scheduled for replacement.	No natural banklines through culvert. Some restriction of floodplain and channel function.
50	HWY 89 S	Fall Creek	Large Concrete Arch Pipe	Appeared to be operating fine. No concern.	Elevated water velocities could create passage problems.	No natural banklines through culvert. Some restriction of floodplain and channel function.

59	HWY 89 S	Cabin Creek	Concrete Box with Baffles	Concern. Excessive channel scour downstream of structure.	Elevated water velocities could create passage problems. Large outlet drop could create passage problems.	Culvert is restricting floodplain and channel function, both laterally and vertically.
-	HWY 89 S	Dog Creek	Single Box Culvert	Appeared to be operating fine. No concern.	Due to large spring flows, the culvert was flowing under full pipe conditions. Full pipe conditions are not desirable for fish passage.	Culvert restricts floodplain and channel function.

Table Notes:
1 – Site ID number matches numbers on road-stream crossing figures.

Based on the site visit, there were a few general patterns that can be used to help guide future road-stream crossings designs. Generally speaking, with the exception of a couple road-stream crossings, all sites appeared to be operating fine from an O&M perspective. The one exception was Cabin Creek, where the channel was severely scouring the stream downstream of the road. Fish passage observations are tied to the timing of the site visit. And, in this case, the site visits were performed during spring runoff of a year with a large snowpack, and thus elevated stream and river flows. One common concern was elevated water velocities observed in several road-stream crossings. Stream flows are highly variable daily, seasonally and annually. Because of the dynamic nature of stream flows, observations are timing-specific and reflect the conditions of the day and year.

Many of the crossings restricted the stream channel and/or floodplain. It should be noted that some channel width restriction is common in road-stream crossings that may or may not have been designed to provide long-term aquatic connectivity. And, most road-stream crossings were not designed to provide floodplain connectivity and thus most of them restrict it.

5.5. Recommended Design Approaches for Crossing Replacements

The optimal approach to maintain connectivity for fish and other aquatic species in all types of aquatic habitats is to avoid constructing roads and other potential barriers across them. Where this cannot be accomplished or in replacement designs, road-stream crossings should be designed and constructed in a manner that allows for long-term function of the stream or river and its floodplain. Long-span or “floodplain” bridges are the ideal but most costly solution as they allow for natural river, riparian and floodplain dynamics. Other larger structures that fully span the waterbody and stream or river banks provide the next best approach to ensure long-term passage. This would also be the best solution for the northern river otter *(Lontra canadensis*) that has been identified as a species of concern to biological conservation (see section 2.2).

A highly effective approach, when long-span or “floodplain” bridges are not an option due to site-specific or economic reasons, is to use culverts or short-span bridges that simulate a natural stream channel through them. This approach is called “stream-simulation” and relies upon the following general principle:

> “…designing crossing structures (usually culverts), that creates a structure that is as similar as possible to the natural channel. When channel dimensions, slope and streambed structure are similar, water velocity and depths also will be similar. Thus, the simulated channel should present no more of an obstacle to aquatic animals than the natural channel (USDA 2008, Introduction, page xxiii).”

One additional benefit to large spanning bridges, or stream-simulation designs, is they provide flood conveyance and have sufficient area for natural sediment and woody debris transport to occur through the crossing because they are wider and have larger openings. By allowing natural channel function and the passage of larger flows unimpeded, the infrastructure will have a longer lifespan with less risk of failure and need for costly replacements, or repetitive O&M.

Some states, such as Maine, have recommended minimum widths for new road-stream crossings to ensure they are designed to accommodate channel function and aquatic organism passage. In Maine, minimum culvert widths are recommended to be 1.2 times the stream bank-full channel width or larger to accommodate aquatic organism passage (MDOT, 2008). In addition, there are many good design manuals, such as Water Crossings Design Guidelines by the Washington Department of Fish and Wildlife, that clearly outline the engineering process for design and construction of road-stream crossings that are environmentally sensitive and will ensure long-term aquatic connectivity (WDFW, 2013).

A possible framework for addressing road-stream crossing replacement, where a main objective is long-term aquatic connectivity, would be to approach each site with one of four potential replacement strategies including:

1. Full spanning bridge.
2. Bridge with banklines through the structure.
3. Culvert with stream simulation and banklines through the structure.
4. Multiple structures - main channel with stream simulation culvert and overflow channels with smaller structures for flow conveyance only.

The order they are listed above is the order in which they would provide “better” or more aquatic connectivity – full spanning bridges provide more aquatic connectivity than smaller bridges with banklines only. And, the order shown above also matches the initial financial investment for construction with full spanning bridges being the largest initial investment. Three examples of new road-stream crossings that provide long-term aquatic connectivity are included as conceptual designs in Chapter 6.

5.6. Prioritization Moving Forward

The scope of work for this project did not include new data collection or development of a prioritization strategy or framework for replacement of road-stream crossings; however, WTI and many members of the stakeholder group recommend that some form of road-stream crossing prioritization take place to guide future replacements. The exact details of a prioritization strategy should be developed with input from stakeholders.

Prioritizing crossings is a good way to identify the crossings that represent the greatest risk to fish and aquatic species passage and would benefit the ecosystem most from improvements. There are a number of prioritization strategies that can be followed. Generally, prioritization is done by looking at all road-stream crossings on a watershed-scale or larger area. Information is gathered for each road-stream crossing and watershed and can be grouped into four broad categories or factors: (1) passability or “barrierity” of each crossing, (2) ecological value of the river or stream, (3) constructability or economic considerations, and (4) native species conservation value. A numeric value is given to data within each factor. The values are summed for all categories to provide a relative ranking of road-stream crossings. This ranking yields the prioritization or the order.

Passability or “barrierity” of a crossing refers to the severity or degree to which a crossing acts as a barrier to fish or aquatic species passage. The most common physical features in road-stream crossings that create barriers to upstream fish passage include outlet drop height, shallow water depth, and high velocity (Burford et al., 2009; Baker and Votapka, 1990; Fitch, 1995). Typically, road-stream crossings are grouped into categories based on the level of impedance they create and often include the following: (1) no passage issues, (2) some degree of passage restriction, (3) barrier to passage. Categorization of passability is based upon physical characteristics of a site, such as structure type, outlet drop height, structure slope, and can be either assigned using direct or indirect observations. Direct observations of passage are more time consuming and costly as they require some means of directly measuring passage, through radio telemetry, mark-recapture or other field studies, at a given road-stream crossing. Most prioritization strategies assign a level of impedance indirectly, using thresholds based on direct observations. For example, outlet drops can create passage problems for small fish or non-leaping fish species; therefore, if a structure had an outlet drop it could present passage problems.

The second part of a prioritization matrix or framework is the ecological value of replacing or retrofitting a crossing. The ecological value framework typically involves categorizing the waterbody crossed by the road-stream crossing in terms of two broad categories: habitat value and connectivity value. Habitat value quantifies the quality of the river, stream or waterbody habitat including riparian and floodplain areas and the watershed. Connectivity value includes the proximity of the crossing to potential barriers both upstream and downstream. It can also be used to quantify the amount of habitat that would be connected, or restored, if the crossing were replaced. The factors used to assign ecological value within a prioritization matrix for connectivity could also reflect the goals of the Wyoming Game and Fish Department’s Strategic Habitat Plan. This plan outlines how WGFD and its partners will accomplish its goals of habitat protection and enhancement.

Constructability or economic considerations are used to define the complexity and cost for replacement of a structure. A constructability framework should quantify the cost of structure replacement, which inherently incorporates the complexity of reconstruction. Economic considerations inform the prioritization by allowing for strategic decisions to be made and to prepare a replacement timeframe and schedule. For example, a replacement strategy may be to first replace crossings that were identified as having high ecological value, but low cost. This approach would yield greater connectivity for less investment. Or, it may be decided to place more emphasis on replacing an especially problematic road-stream crossing that would yield a large amount of ecological value, regardless of the capital investment.

If native species conservation is a priority for a given watershed or region, then consideration of that priority should be included in a prioritization framework. For example, in some cases, to protect native species from non-native species, it may be desirable to create a barrier at a crossing or to not remove an existing barrier. One strategy to protect native cutthroat trout from non-native rainbow trout in parts of the greater Yellowstone region, is to purposely create or leave a passage barrier in the stream or river. This then purposely isolates native cutthroat (upstream) and protects them from competition from non-native species (downstream). Considerations like this can be added to the stream crossing evaluation process and development of mitigation strategies.

During this project, one key data gap that was identified is site-specific crossing information. Specifically, physical information about each structure including type of crossing (bridge, culvert, etc.), size, length, slope, span, material, upstream and downstream river or channel features, headwall configuration, and other key features. For any future prioritization to commence, physical information about each crossing should be collected.

Until a prioritization strategy is developed, one can adopt a policy to consider fish passage when making any changes to stream or river crossings associated with roads. Reaching out to stakeholder will result in information of the local situation and suggestions for the design of the stream or river crossing.

6. SITE SPECIFIC RECOMMENDATIONS

6.1. Highway Types and Recommendations for Terrestrial Wildlife

This chapter describes suggestions for potential future mitigation measures along the highways in Teton County (summarized in Figures 30 and 31). The researchers distinguish between recommendations for the following types of highways:

- Highways that have been reconstructed recently and that included wildlife mitigation or highways for which the reconstruction and associated wildlife mitigation was already decided on by the time the project was conducted (i.e. southern portion of section 3 (Hoback Jct- South end of South Park Loop, US Hwy 26/89/191) and section 5 (Togwotee Pass, US Hwy 26/287)).

  The researchers did not formulate mitigation suggestions for these highway sections.

- High volume roads (about 10,000 vehicles/day or more) regardless of the design speed and speed limit (i.e. northern portion of section 3 (South end South Park Loop - Jackson, US Hwy 26/89/191), section 4 (Jackson – Gros Ventre River, US Hwy 26/89/191), and the eastern portion of section 6 (Jackson – Wilson, WY 22)).

  A physical separation of wildlife and traffic is essential because of the high traffic volume. Wildlife may avoid crossing the highway because of the high traffic volume, and sudden braking for wildlife on high volume roads could lead to rear-end collisions. In addition, most of these road sections have a design speed and posted speed limit that is too high for drivers to be able to stop in time to avoid a collision in the dark.

  The researchers suggest a combination of wildlife fences and wildlife crossing structures. The wildlife fences keep large mammal species off the highway and guide them towards the crossing structures. The underpasses and overpasses provide safe crossing opportunities and they may also reduce the likelihood that animals breach the fences as there is a more convenient way to reach the other side of the highway.

  Depending on the target species, the researchers suggest different types and dimensions of wildlife crossing structures (Table 9). The location of the crossing structures is extremely important to the use they receive; the crossing structures need to be placed where animals are currently crossing the highway or where they are known to come close to the highway. Gradual approaches that allow the animals to see to the other side of the highway are important, especially in open habitat (i.e. flat terrain with grasslands or sagebrush).

  The road section through the south part of Jackson (east and south-east of High School Butte) and part of Broadway cannot be fenced because of the many sideroads, driveways and parking lots. Therefore, the researchers suggest improving visibility for drivers through more and better streetlights. The streetlights would not be installed near the suggested wildlife overpass on Broadway so that wildlife is not discouraged from using the overpass. The streetlights would be designed to project light on the road surface and minimize light shining up to minimize light pollution. Any proposed lighting in Teton County would need to take dark skies initiatives into account.

Table 9: Suggested type and dimensions of crossing structures for possible target species in Teton County.

Target species	Crossing structure type	Width (from the animal's perspective)	Height
Elk, moose, or rare carnivores such as grizzly bear, Canada lynx and wolverine	Wildlife overpasses	About 50-70 m (164-230 ft)	n/a
	Long bridges	At least about 30-50 m (98-164 ft)	At least about 7 m (23 ft)
Bighorn sheep or wolf	Long bridges	At least about 30-50 m (98-164 ft)	At least about 7 m (23 ft)
Mule deer	Underpasses	At least about 7 m (23 ft)	About 4 m (13 ft)

- Medium volume roads (about 5,000 vehicles per day) with a high design speed and a high speed limit (55-65 mi/h) (i.e. section 2 (west of Hoback Jct, US Hwy 89/26) and section 6 (west of Wilson, WY22).

  A physical separation of wildlife and traffic is preferred, especially if traffic volume is expected to increase. Wildlife may avoid crossing the highway because of the high traffic volume, and sudden braking for wildlife could lead to rear-end collisions. In addition, most of these road sections have a design speed and posted speed limit that is too high for drivers to be able to stop in time to avoid a collision in the dark.

  However, in some cases where the terrain is not suitable for an underpass or an overpass, at grade crossing opportunities (with or without an animal detection system) may be considered. Animal detection systems can be implemented as a stand-alone measure over long distances, or they can be used in association with fencing, where the animal detection system is situated at a gap in the fence (the gap should be present on both sides of the highway).

  A standard animal detection system detects large animals as they approach the highway. This activates warning signs that urge drivers to be more alert and/or to slow down. The researchers suggest accompanying the warning signs with an advisory or mandatory speed limit reduction to 45 mi/h (72 km/h) to increase the chances that drivers can avoid hitting wildlife on the highway (Huijser et al., 2017).

  Alternatively, we suggest an alternative approach where the road sections with a gap in the wildlife fence on both sides of the highway may be lighted when a vehicle approaches. This is essentially a “vehicle detection system” (e.g. through detection loops in the pavement) rather than an "animal detection system". This would light up the crossing area, allowing drivers to see potential wildlife on the highway as they approach. When the street lights are turned on, warning signs may also be activated that include an advisory speed of 45 mi/h (72 km/h). Note that street lights may also scare wildlife away from the safe crossing opportunity and that the activated lights may make it less likely that they will use the crossing location in the future. This is an untested mitigation system and, if adopted, should be treated as experimental and evaluated carefully for effectiveness.

At-grade crossings in combination with wildlife fences should have barriers in place (e.g. electric mats or electric concrete) to encourage animals to cross the highway and discourage them from entering the fenced road corridor.

- Medium volume roads (about 5,000 vehicles per day) with a low design speed and a low speed limit (35-45 mi/h) (i.e. section 7 (Jct with Hwy 22 – Grand Teton National Park, WY 390)).

  A physical separation of wildlife and traffic is preferred, especially if traffic volume is expected to increase. Wildlife may avoid crossing the highway because of the high traffic volume, and sudden braking for wildlife could lead to rear-end collisions. However, the design speed and the posted speed limit is within the range that about 50% of the drivers should be able to stop in time after detecting a large mammal on the road in front of them. Therefore, one could choose to not implement additional measures. Nonetheless, about 50% of the drivers have vehicles with headlights that do not cover a sufficiently long distance to be able to stop in time for a large mammal on the road. In addition, animals that come in running from the side at distances shorter than the range of the head lights, leave even less time and distance to avoid a collision.

- Low volume roads (about 1,500 vehicles per day) with high design speed and high speed limit (55-65 mi/h) (i.e. section 1 (east of Hoback Jct) and section 5 (Togwotee Pass).

  A physical separation of wildlife and traffic is preferred, especially if traffic volume is expected to increase. Low traffic volume reduces the risk of rear-end collisions because of sudden braking, but it remains a risk. In addition, most of these road sections have a design speed and posted speed limit that is too high for drivers to be able to stop in time to avoid a collision in the dark.

  However, in some cases where the terrain is not suitable for an underpass or an overpass, at grade crossing opportunities (with or without an animal detection system) may be considered, either as a stand-alone measure over long distances or at a gap in the fence (the gap should be present on both sides of the highway).

  As above, we recommend either a standard animal detection system with driver warning sign and reduced speed limit, or in combination with a "vehicle detection system" that lights up the crossing area when a vehicle approaches.

Lighting the road at the at-grade crossing opportunities and improving the visibility for drivers, and scaring the wildlife away from the crossing area may be especially useful if semi-trucks make up a relatively high percentage of the traffic volume since semi-trucks require greater stopping distances and drivers and their vehicles are at lower risk of incurring human injuries and vehicle damage when they hit large mammals compared to passenger vehicles, reducing driver motivation to avoid wildlife collisions. Note that street lights may also scare wildlife away from the safe crossing opportunity and that the activated lights may make it less likely that they will use them in the future.

The mitigation recommendations for road sections that ranked highest based on a combination of human safety and economics, and on biological conservation were summarized in Table 10.

Table 10: The mitigation recommendations for road sections that ranked highest based on a combination of human safety and economics, and on biological conservation (see also Appendix I).

Description road section	Hwy section	Hwy number	Start m reference post	End mi reference post	Length (mi)	Rank	Target species	Recently reconstructed?	Recently mitigated?	Fences/barrier walls	Overpass	Underpass	At-grade	Improved street lighting	Low posted speed limit
Spring Gulch - Jct WY 390	6	22	0.6	4.3	3.8	1	Mule deer, elk, moose	No	No	Yes	2	5		No	
Snake River - Game Creek area	3	S 89	146.0	147.7	1.8	2	Mule deer, elk	Yes	Yes	Recently mitigated					
Camp Creek area - Hoback Jct	1	191	158.4	163.3	5.0	3	Mule deer, elk, bighorn sheep	No	No	Yes	5*		5*	Yes*	
South Park Loop (south end) - Jackson	3/ 4	S/N 89	149.6	155.7	6.2	4	Mule deer, elk	No	No	Yes	2			Yes	
Jct Hwy 22 - N Lily Lake Lane	7	390	0.0	1.2	1.3	5	Moose	No	No	Yes		1		No	Yes
Dog Creek - Hoback elk feed ground area	2	26	136.0	138.0	2.1	6	Mule deer, elk	No	No	Yes	2*		2*	Yes*	
Fish Hatchery	4	N 89	157.2	158.3	1.2	7	Mule deer, elk	No	No	Yes	1	1			
Blackrock Ranger Station area	5	26	7.2	8.8	1.7	8	Moose, Elk, Large carnivores	Yes	No	Recently locally mitigated					
Weigh Station area	6	22	15.5	16.5	1.1	9	Moose, Large carnivores	No	No	Yes	1*		1*	Yes*	
Wilderness Dr - Snake River Ranch Rd	7	390	2.8	4.8	2.1	10	Mule deer, moose	No	No	No					Yes
Horse Creek area	3	S 89	142.5	142.5	0.1	11	Mule deer, elk	Yes	Yes	Recently mitigated					
Total					26.4						5-13*	7	8*		

*Note that wildlife fences and wildlife crossing structures (especially overpasses for elk) are the preferred option over at grade crossing opportunities (with or without lighting).

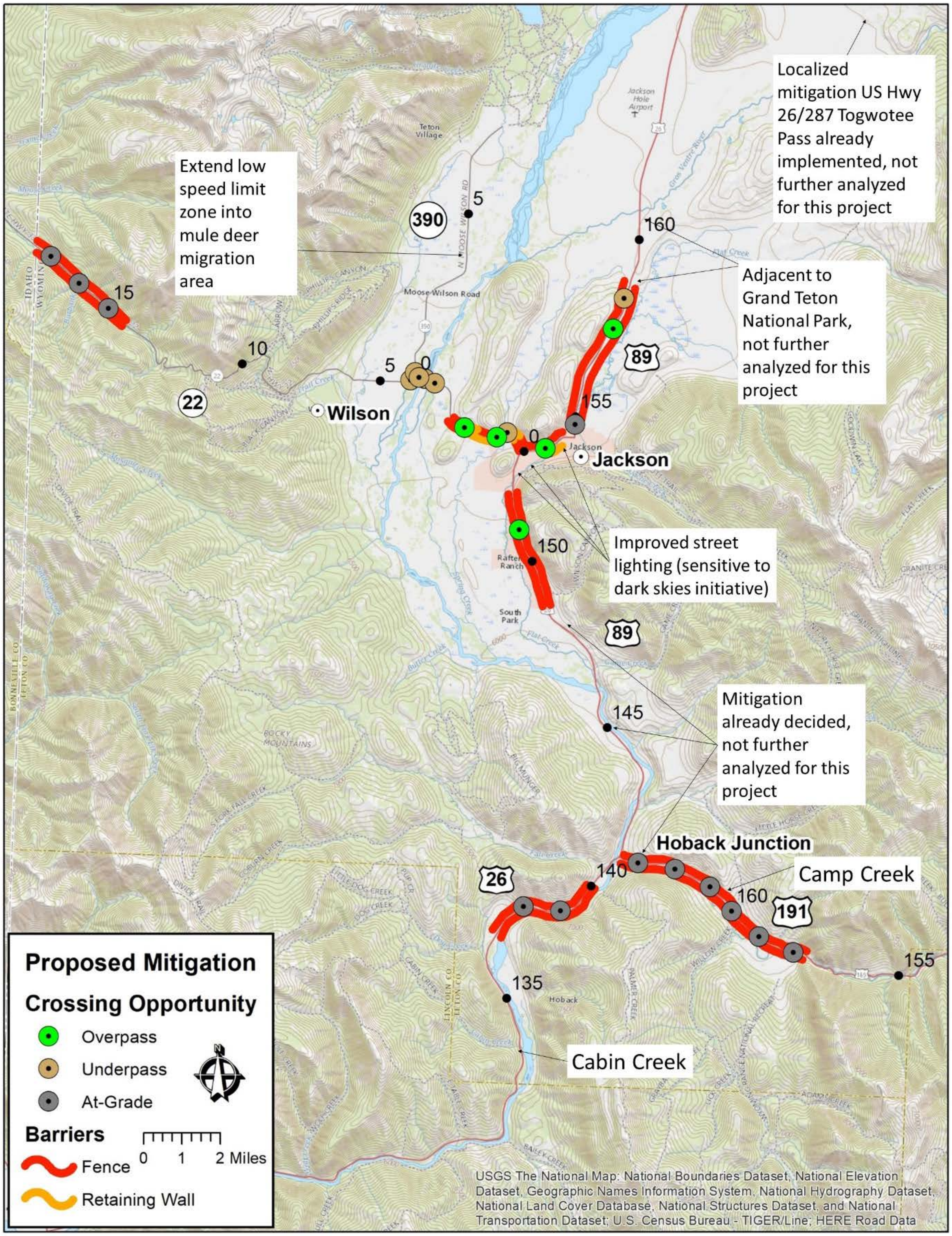


Figure 30. Suggestions for potential future mitigation measures. Note that the wildlife fences in combination for wildlife crossing structures is the preferred option over at-grade crossing opportunities.

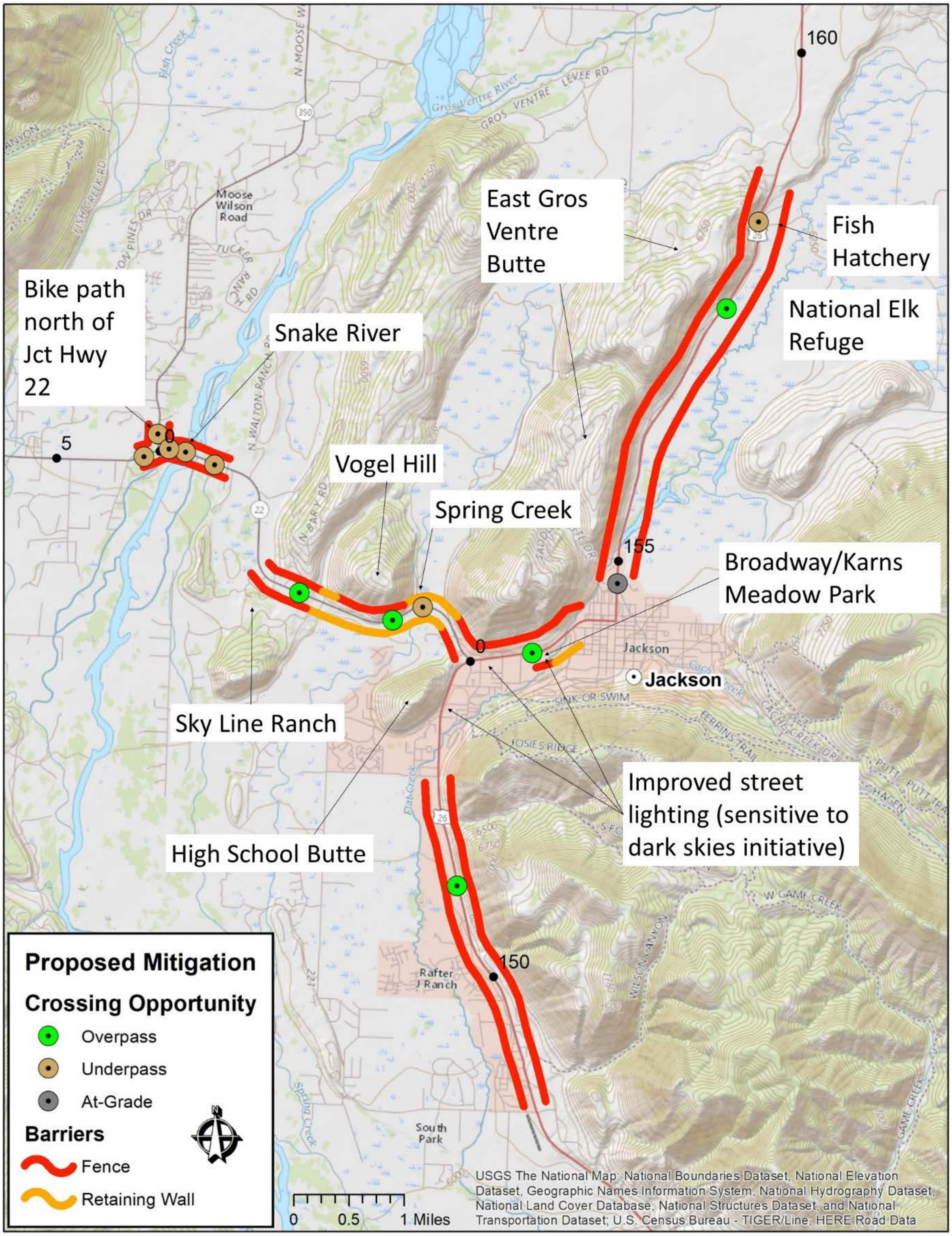


Figure 31. Suggestions for potential future mitigation measures (zoomed in around Jackson). Note that the wildlife fences in combination for wildlife crossing structures is the preferred option over at-grade crossing opportunities

The mitigation recommendations for the road sections that ranked highest based on a combination of human safety and economics, and on biological conservation are discussed in greater detail below.

Rank 1, Road section 6, WY 22, Spring Gulch - Jct WY 390

A. Spring Creek – Ridge west of Coyote Canyon Rd.

This is a high collision area for mule deer (Springhill Creek-Coyote Canyon Rd, elk (especially around the ridge west of Coyote Canyon Rd), and large wild animals in general (especially at the base of Vogel Hill and the ridge west of Coyote Canyon Rd). This is also an important migration or movement area for mule deer, elk and moose (the latter especially at the ridge west of Coyote Canyon Rd). The researchers recommend barriers to keep wildlife off the highway and underpasses (mule deer) and overpasses (elk and moose) to provide safe crossing opportunities. Use barrier walls integrated into the road bed instead of wildlife fences where landscape aesthetics are a concern and where the view of the landscape, including mountains, from the road should not be obstructed. The researchers suggest ending the barriers (especially wildlife fences) west of the ridge west of Coyote Canyon Rd as this is a flat open section where the view of the mountains should remain unobstructed. Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete. Incorporate wildlife jump-outs allowing large mammals to escape the road corridor. The researchers recommend the following crossing structures in this road section (more details in the information sheets with drawings for selected structures):

- Bridge or bottomless culvert at Spring Creek for mule deer. Note that the structure should not have division or supporting walls. If the structure needs support, consider pillars rather than walls so the animals can see through the structure and not have the walls make the structure seem much narrower.
- Wildlife overpass at Vogel Hill for mule deer and elk.
- Wildlife overpass at the ridge west of Coyote Canyon Rd for elk and moose, and mule deer.

Note that while an underpass at Coyote Canyon Rd seems logical based on the topography, an underpass is not what would be recommended for elk or moose (only suitable for mule deer). In addition, the specific topography at this location would require the animals to descend into a deep bowl when approaching the road from the south. Therefore, an underpass at Coyote Canyon Rd may also not function well for mule deer, and the researchers suggest investing in an overpass at the ridge just to the west instead.

B. Snake River floodplain

This is a high collision and important movement area for moose. The researchers recommend barriers to keep large mammals, specifically moose, off the highway and underpasses to provide safe crossing opportunities. Note that the road is already on an embankment and that a bridge or wide bottomless culvert would be far easier to construct than a wildlife overpass (though a wildlife overpass is, in general, preferred over an underpass for moose). Use barrier walls

integrated into the road bed instead of wildlife fences where landscape aesthetics are a concern and where the view of the landscape, including mountains, from the road should not be obstructed. The researchers suggest ending the barriers (especially wildlife fences) at or just beyond the floodplain of the Snake River, and to not affect the landscape aesthetics in the open areas where the view of the mountains should remain unobstructed. Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete. Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
The researchers recommend the following crossing structures in this road section (more details in the information sheets with drawings for selected structures):

- Bridge across Snake River, make west and east bank passable for moose.
- Bottomless culvert or bridge on the east bank of the Snake River between the parking area and the start of the bridge on the east bank, especially if the east bank of the bridge cannot be made suitable for moose. Note that the structure should not have division or supporting walls. If the structure needs support, consider pillars rather than walls so the animals can see through the structure and not have the walls make the structure seem much narrower.
- Bottomless culvert or bridge on the west bank of the Snake River between the west bank of the Snake River and the junction with WY 390. Note that the structure should not have division or supporting walls. If the structure needs support, consider pillars rather than walls so the animals can see through the structure and not have the walls make the structure seem much narrower.
- Bottomless culvert or bridge on the west bank of the Snake River between the junction with WY 390 and the western edge of the floodplain. Note that the structure should not have division or supporting walls. If the structure needs support, consider pillars rather than walls so the animals can see through the structure and not have the walls make the structure seem much narrower.

Rank 3, Road section 1, US Hwy 189/191, Camp Creek area - Hoback Jct

This road section has a relatively high concentration of elk-vehicle collisions. It is an important movement or migration area for mule deer and elk. In addition, bighorn sheep are licking road salt around Camp Creek. Because of the relatively low traffic volume (about 1,600 vehicles per day), this would be a suitable location to experiment with at-grade crossing opportunities; e.g. a gap in wildlife fences on both sides of the highway. Effectiveness in collision reduction can potentially be enhanced through lighting the crossing areas when traffic approaches. Alternatively, an animal detection system can be installed at the gaps in the fence. However, the most robust and preferred mitigation measure is wildlife fences in combination with underpasses and overpasses.

Rank 4, Road section 3, US Hwy 26/89/191 South Park Loop (south end) - Jackson

This road section has a very high concentration of mule deer and high concentration of elk-vehicle collisions. There is important winter habitat for mule deer on both sides of the highway. It is also an important mule deer migration corridor.

The researchers recommend barriers to keep wildlife off the highway and overpasses to provide safe crossing opportunities. Use barrier walls integrated into the road bed instead of wildlife fences where landscape aesthetics are a concern and where the view of the landscape, including mountains, from the road should not be obstructed. Barriers can also be used where the topography has a sudden drop. The researchers suggest not having fences around the south-east side of Jackson or through the heavily developed road section through Jackson (except on the west side at East Gros Ventre Butte and on the east site at Karns Meadow Park). Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete. Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.

The researchers recommend the following crossing structures in this road section (more details in the information sheets with drawings for the two structures):

- Overpass south of Jackson.
- Overpass at Karns Meadow Park.

These overpasses have the potential to become a more important element in mule deer migration corridor as the highway and the town of Jackson increasingly block the mule deer movements across the highway at the base of High School Butte (see section 6.3).

The researchers also suggest improved street lighting in the road section through Jackson with commercial and residential buildings. The purpose of the lighting is to improve the visibility of mule deer and other large mammals to drivers and perhaps also discourage large mammals from crossing the highway at-grade. Note that the light should be directed down towards road surface, minimizing light pollution.

Rank 5, Road section 7, WY 390, Jct Hwy 22 - N Lily Lake Lane

This is a high collision and important movement area for moose. The preferred alternative from an ecological perspective is to reroute the southern portion of WY 390 and connect to WY 22 further to the west, outside of the floodplain and riparian area. Should this be considered infeasible, the researchers recommend barriers to keep large mammals, specifically moose, off the highway for the first 0.2-0.3 miles north of the junction with Hwy 22, and an underpass just north of the junction with WY 22 to provide a safe crossing opportunity. Note that the road is already on an embankment and that a bridge or wide bottomless culvert would be far easier to construct than a wildlife overpass (though a wildlife overpass is, in general, preferred over an underpass for moose). Use barrier walls integrated into the road bed instead of wildlife fences where landscape aesthetics are a concern and where the view of the landscape, including mountains, from the road should not be obstructed. The researchers suggest ending the barriers (especially wildlife fences) where the residential areas with access roads and driveways start (about 0.3 miles north of the junction with WY 22). Mitigate access roads in the fenced section with gates, wildlife guards, or electric mat or electric concrete. Incorporate wildlife jump-outs allowing large mammals to escape the road corridor. Further north the researchers suggest keeping the relatively low posted speed limit in place (45 MPH day, 35 MPH night).

The researchers recommend the following crossing structure in this road section (more details in the information sheet):

- Bottomless culvert or bridge just north of the junction with WY 22, designed for moose. Note that the structure should not have division or supporting walls. If the structure needs support, consider pillars rather than walls so the animals can see through the structure and not have the walls make the structure seem much narrower.

Rank 6, Road section 2, US Hwy 89/26, Dog Creek - Hoback elk feed ground area

This road section has a high concentration of mule deer and elk-vehicle collisions. It is an important movement and migration area for mule deer and elk. Because of the relatively low traffic volume (about 4,000-5,000 vehicles per day), this would be a suitable location to experiment with at-grade crossing opportunities; e.g. a gap in wildlife fences on both sides of the highway. Effectiveness in collision reduction can potentially be enhanced through lighting the crossing areas when traffic approaches. Alternatively, an animal detection system can be installed at the gaps in the fence. However, the most robust and preferred mitigation measure is wildlife fences in combination with underpasses and overpasses.

Rank 7, Road section 4, US Hwy 26/89/191, Fish Hatchery area

This road section is a high collision area for elk and mule deer. It is an important elk migration corridor, and in the past also for bighorn sheep. There is important winter habitat for elk on the east side of the highway on the National Elk Refuge. A fence with jump-outs (west to east passage only) is present on the east side highway only (not on west side).

The researchers recommend barriers to keep wildlife off the highway and an underpass (mule deer) and an overpass (elk) to provide safe crossing opportunities. Use barrier walls integrated into the road bed instead of wildlife fences where landscape aesthetics are a concern and where the view of the landscape, including mountains, from the road should not be obstructed. The researchers suggest ending the barriers (especially wildlife fences) Just north of the built-up area of Jackson and at the mi 158.8 (this is where the west side of the highway becomes Grand Teton National Park). For additional suggestion on mitigation measures between Jackson and the Gros Ventre River bridge see Huijser and Begley (2015). Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete. Incorporate wildlife jump-outs allowing large mammals to escape the road corridor. The researchers recommend the following crossing structures in this road section (more details in the information sheets with drawings for the overpass):

- Overpass south of Fish Hatchery turn-off (for mule deer, elk, and perhaps in the future bighorn sheep).
- Underpass at Fish Hatchery turn-off where the road is high on the embankment (for mule deer).

Rank 9, Road section 6, WY 22, Weigh Station area

This road section has a relatively high concentration of moose-vehicle collisions. It is an important movement and migration area for moose and rare carnivores.

Because of the relatively low traffic volume (about 5,000-6,000 vehicles per day), this would be a suitable location to experiment with at-grade crossing opportunities; e.g. a gap in wildlife fences on both sides of the highway. Effectiveness in collision reduction can potentially be enhanced through lighting the crossing areas when traffic approaches. Alternatively, an animal detection system can be installed at the gaps in the fence. However, the most robust and preferred mitigation measure is wildlife fences in combination with underpasses and overpasses. Steep terrain makes it challenging to build underpasses or overpasses with gradual approaches though. Note that overpasses would be recommended for moose over underpasses.

Rank 10, Road section 7, WY 390, Wilderness Dr - Snake River Ranch Rd

This is an important area for mule deer and moose movement and migration. This road section has many access roads and driveways, is curvy and has limited sight distances. Since this is currently not a high collision area, the researchers suggest keeping the relatively low posted speed limit in place (45 MPH day, 35 MPH night) and monitoring road killed animals and potential increase in barrier effect of the road. Should the road mortality or barrier effect substantially increase, reevaluate the situation and consider additional mitigation measures.

6.2. Indicative Costs Mitigation Measures

The researchers summarized the indicative costs of different types of mitigation measures (Table 11). Note that these costs are indicative; the true costs for a site are only known after the bidding and construction process are completed. The costs depend on many factors, including the state of the economy, remoteness, and the local conditions. Also note that the costs estimates are based on construction costs and that the projected life span of the different mitigation measures ranges widely. For example, an animal detection system may need to be replaced after 10 years, a wildlife fence after 25 years, and a concrete crossing structure after 75 years. Therefore, it is important to not only evaluate the initial construction costs, but also the costs per year the mitigation measure is in operation (see e.g. Huijser et al., 2009). One of the outcomes of such life span analyses is that while it may seem less expensive to implement animal detection systems based on initial construction costs, the costs per year for animal detection systems is projected to be higher than for wildlife fences in combination with wildlife overpasses and underpasses.

Table 11: Indicative costs of different types of mitigation measures (Huijser et al, 2009, 2015b, 2016b, unpublished data).

Measure	Indicative costs (in 2007 US$)
Wildlife fences (8 ft tall, including dig barrier, both sides Hwy)	± $160,900/mi ($100,000/km)
Jump-out	± $8,000/jump-out
Wildlife guard at access road	± $30,000/guard
Electric mat/concrete in travel lanes	± 30,000/mat
Wildlife overpass (50-60 m wide)	± $5,000,000-10,000,000/structure
Over span bridge, varying lengths	± $500,000–3,000,000/structure
Wildlife underpass (large culvert)	± $500,000/structure
Animal detection system, radar based	± $321,800/mi ($200,000/km)

6.3. Strategic Approach Based on the Needs for Individual Species

Addressing direct road mortality and the barrier effect of highways and traffic for individual species that have a biological conservation concern requires a tailored approach that may be different from the identification and prioritization process used here (see section 4.6.3). For example, taking steps to safeguard migration for specific species may require that mitigation measures are implemented at multiple locations along multiple highways in order to safeguard the whole migration route. Not implementing mitigation along one or several locations may mean that the future of the migration route is still jeopardized even if one location is mitigated. Similarly, taking steps to contribute to a higher level of population viability for selected threatened or endangered species may require a strategy where mitigation measures are implemented where the highest benefits are achieved in terms of increased population viability rather than other factors such as greatest threat to human safety.

The researchers present an example of what type of strategy may be needed to safeguard mule deer migration in Teton County, and Jackson specifically (Figure 32, 33). Jackson and surrounding developments and US Hwy 26/89/191 and WY 22 cut through several mule deer migration corridors (Figure 32). Mule deer move through residential and commercial properties, especially east and south-east of High School Butte and between the Jct with Hwy 22 and Karns Meadow and the green corridor to Snow King (Figure 33). This is also where traffic hits many mule deer. Human-mule deer conflicts are apparent, and the long-term future of this migration corridor seems in jeopardy. In this context, the suggested overpass across Broadway that would provide a safe path between East Gros Ventre Butte and Karns Meadow and other areas further to the south seems essential. In addition, connectivity between the northern edge of town (near Flat Creek bridge) and the fence around the National Elk Refuge are essential. This may have to be an at-grade crossing as the topography does not allow for an underpass that is tall enough for mule deer. Fortunately, the speed limit is low (25 mi/h). However, there are no obvious safe crossings that could be implemented for mule deer between the Jct with Hwy 22 through the south end of Jackson. An overpass would require a substantial landing area on the east side of the highway, but this area is built up (commercial and residential) (Figure 33). In addition, the approach on the east side would still be through residential and commercial properties. This suggests that this migration path may not have a long-term future (Figure 33). It suggests that providing alternate routes that get mule deer to cross US Hwy 26/89/191 further to the south may be what is needed in the long term to preserve the mule deer migration. In the meantime, the current path between High School Butte and the area to the east should not be blocked off; the researchers do not suggest fences that would keep the mule deer from moving through Jackson and crossing the highway. The researchers do suggest improved street lighting to reduce the probability of collisions in this road section. The example above illustrates that coordinated measures may be needed that go beyond mitigating current hotspots for wildlife-vehicle collisions and where wildlife currently cross the highways successfully.

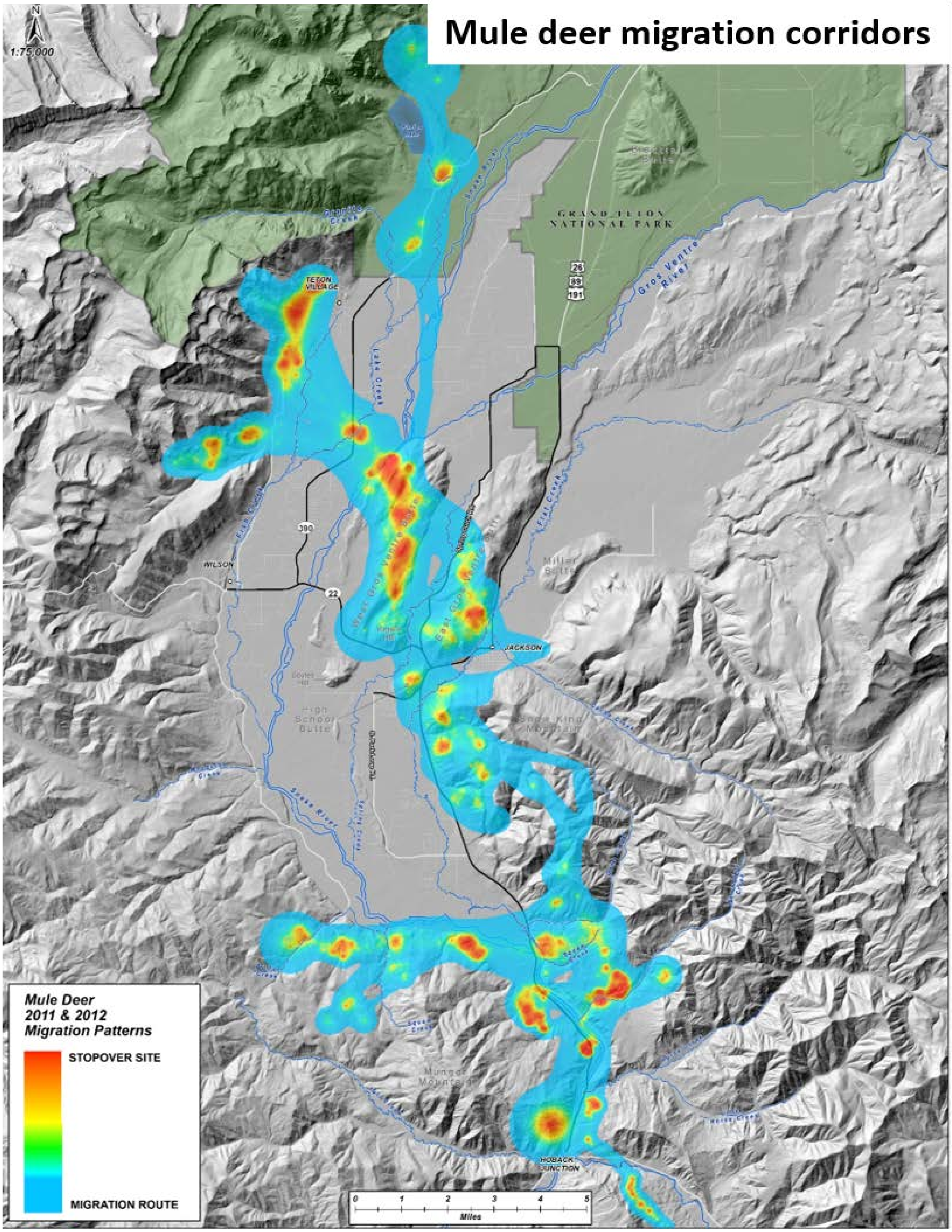


Figure 32. Mule deer migration corridors (Riginos et al., 2016).

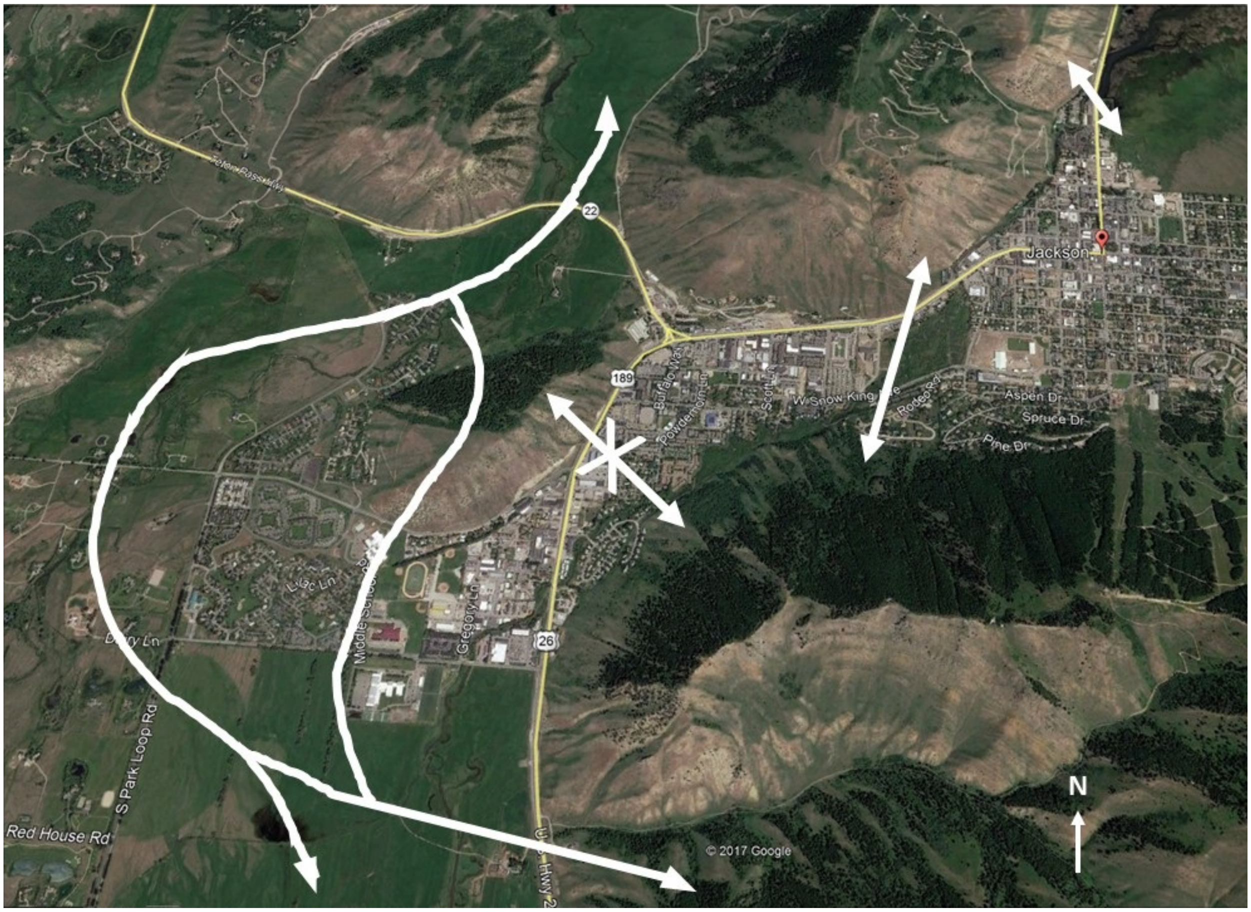


Figure 33. (Potential) mule deer migration corridors through and around Jackson.

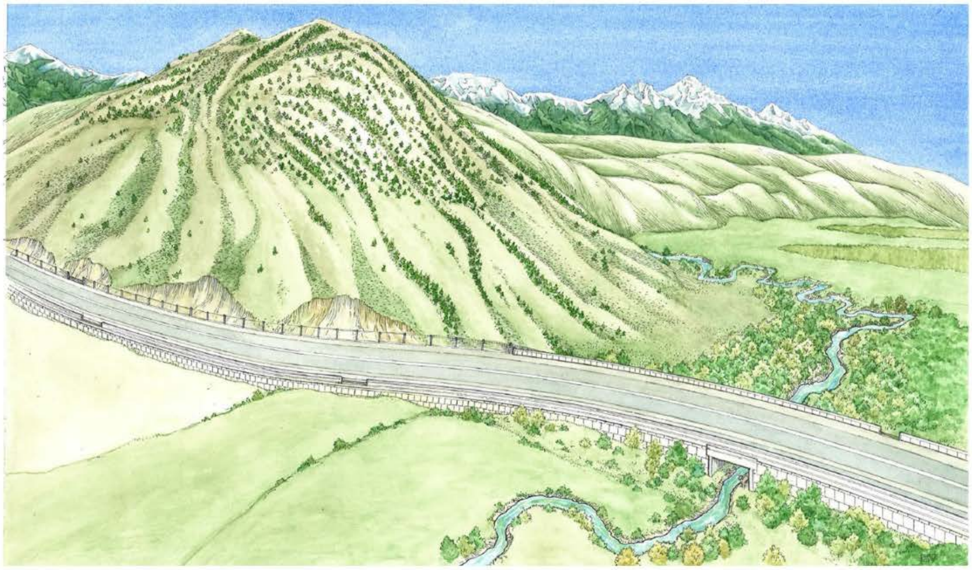
6.4. Conceptual Drawings of Selected Mitigation Measures

The following pages show images and conceptual drawings of what different mitigation measures could look like in Teton County (Figures 34 through 48). Note that the locations for the conceptual drawings were chosen in part because of differences in road, wildlife, stream, and other landscape characteristics. These different characteristics allowed for an illustration of different potential solutions. However, just because a certain mitigation is shown at a recognizable road section, does not necessarily mean that that is the best possible solution. For example, the researchers show an at-grade crossing along Highway 189/191 between Camp Creek and Hoback Jct because that road section has low enough traffic volume. Nonetheless, the researchers also state that wildlife fences in combination with wildlife crossing structures would be the preferred solution.

Note that the drawings are suggestions. They illustrate the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel of land, but they do relate to recognizable road sections.

Draft Conceptual Mitigation Suggestion

WY 22, Spring Creek



Situation

- Important movement/migration area for mule deer and elk.
- Moderate collision concentration for mule deer and elk.
- Shallow water depth, few natural sediments, potentially a fish barrier at low flows.
- Vistas from road are important, especially in flat open areas.
- 2 lanes, very high traffic volume (19,000 vehicles per day).
- Current Spring Creek Culvert is marginally suitable for mule deer, not for elk.
- Road widening project expected in near future.

Draft Suggestions

- Provide a safe wildlife (mule deer) and a more suitable fish crossing opportunity through replacing the divided box culvert at Spring Creek with a taller, undivided, bottomless structure if and when the highway is reconstructed.
- Consider a wildlife overpass at east side Vogel Hill, predominantly for elk (not depicted in this drawing).
- Keep large mammals from entering Hwy 22 and reduce collisions through wildlife fences (where steep slopes in the background reduce visibility of the fence) and retaining walls (where vistas are important). Note that retaining walls can also be used at other locations where wildlife needs to be excluded from the road and where vistas are important.
- Retaining walls minimize the physical foot print of the roadbed.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
- Livestock fences may be required at crossing structures to keep livestock on designated parcels. Consider using wildlife friendly livestock fences.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 34. Conceptual mitigation suggestion, Rank 1, Section 6, Jct Hwy 22 and WY 390, Spring Creek.

Draft Conceptual Mitigation Suggestion

WY 22 Ridge west of Coyote Canyon Rd

Situation

- Very high elk-vehicle collision area, also mule deer and moose.
- Important for mule winter habitat for mule deer on both sides highway.
- Important mule deer, elk and moose movement area.
- High traffic volume (19,000 vehicles/day)

Draft Suggestions

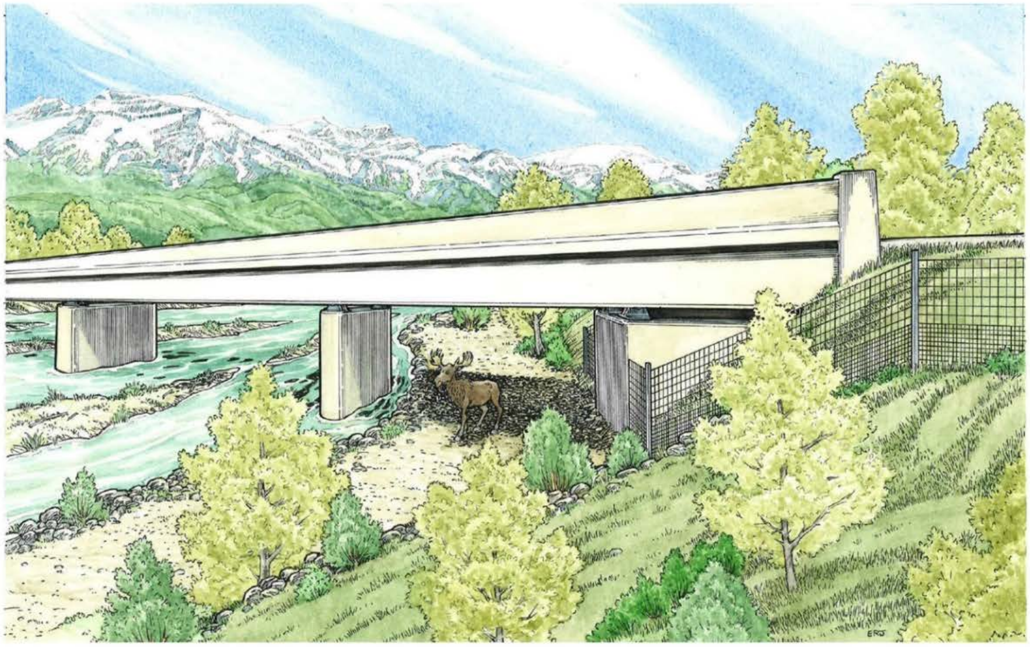
- Provide a safe wildlife (mule deer, elk, moose) crossing opportunity through a wildlife overpass at the ridge (at the “low lying area” in the middle of the ridge as this is where most elk are believed to cross the highway).
- Have the overpass potentially become a more important element in mule deer migration corridor as highway 26/89/191 and the town of Jackson increasingly block the mule deer movements at the base of High School Butte.
- Keep large mammals from entering the highway through wildlife fences, and, where appropriate barrier walls for landscape aesthetics.
- Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 35. Conceptual mitigation suggestion, Rank 1, Section 6, Jct Hwy 22 and WY 390, Ridge Coyote Canyon Rd.

Draft Conceptual Mitigation Suggestion

WY 22, Snake River, East Bank



Situation

- Important habitat for moose.
- Riparian area is potentially important movement/migration area for moose and other species.
- Vistas from road are important.
- 2 lanes, very high traffic volume (19,000/day).
- Current bank on east bank is not suitable for large ungulates (steep, large boulders).
- Bridge spans the entire channel, but lacks natural banks (levees) and floodplain dynamics.

Draft Suggestions

- Provide a safe wildlife (moose) crossing opportunity through “bulbing-out” the levee, potentially a longer bridge, and providing a suitable path for large mammals under the bridge (at least 8 ft wide, 15 ft high).
- Keep large mammals from entering WY 22 through wildlife fences placed low on road bed so that the fence does not block vistas.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
- Incorporate electric mats or electric concrete at fence ends.
- If the east bank cannot be made suitable for moose, provide separate dedicated crossing structure for moose on the east bank.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 36. Conceptual mitigation suggestion Rank 1. Section 6, Snake River, east bank.

Draft Conceptual Mitigation Suggestion

WY 22, Jct Hwy 390 – Snake River

Situation

- Important habitat for moose.
- Very high collision concentration for moose.
- Riparian area is potentially important movement/migration area for moose and other species.
- Vistas from road are important.
- 3 lanes, very high traffic volume (19,000 vehicles/day).
- Current bank on west bank Snake is exposed to high level of human disturbance.
- There is currently a culvert (a few feet diameter) at this location.

Draft Suggestions

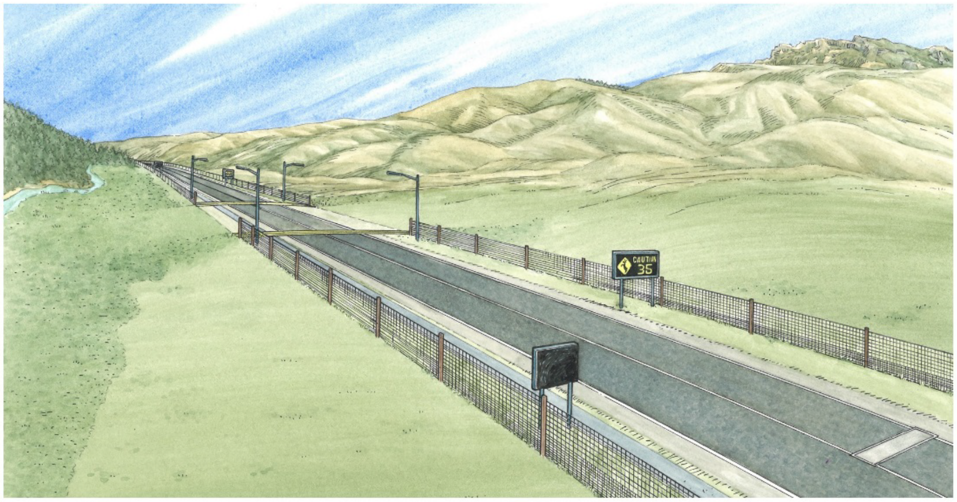
- Provide a safe wildlife (moose) crossing opportunity and connect riparian habitat and floodplain alongside the Snake River through a bottomless structure (e.g. a bridge or a bottomless culvert), and provide a suitable dry path for large mammals under the road (path at least 8 ft wide, at least 15 ft high clearance above path).
- Make the structure (bridge or culvert) as wide as possible (e.g. minimum 30 ft wide, preferably 60-90 ft wide).
- Keep large mammals from entering WY 22 and reduce collisions through wildlife fences placed low on road bed so that the fence does not block vistas.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
- Incorporate electric mats or electric concrete at fence ends.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 37. Conceptual mitigation suggestion Rank 1. Section 6, Jct WY 390 - Snake River.

Draft Conceptual Mitigation Suggestion

US Hwy 189/191, Hoback - Camp Creek



Situation

- High concentration of elk-vehicle collisions.
- Important movement/migration area for mule deer and elk.
- Bighorn sheep licking road salt is a concern.
- 2, lanes, low traffic volume (1,600 vehicles/day), high percentage of semi-trucks.
- Relatively flat terrain immediately adjacent to road.

Draft Suggestions

- Wildlife fences and wildlife crossing structures are preferred (typically more reliable, effective and less risky than detection systems). However, the low traffic volume may allow for experiments with at-grade crossing opportunities.
- Consider at-grade crossing opportunities that are lighted when a vehicle approaches. This is aimed at improving visibility of large mammals to drivers in selected crossing locations and at hazing the animals off the highway when traffic approaches.
- Provide multiple crossing locations (perhaps one per mile or so).
- Keep large mammals from entering US Hwy 189/191 and reduce collisions through wildlife fences.
- Encourage wildlife to cross the highway and keep them from entering the fenced road corridor through electric mats or electric concrete embedded in the travel lanes at the crossing areas.
- When a vehicle is detected (induction loops) approaching a crossing area, activate signs that inform the driver they are approaching a crossing area and advertise a lower speed (35 MPH). At the end of the crossing area have a sign that says “End Wildlife Crossing Area). When no traffic is present, the signs do not display any information (black).
- The lights at the crossing area are only “on” when a vehicle approached. The lights are directed down towards road surface, minimizing light pollution.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 38. Conceptual mitigation suggestion Rank 3, Section 1, Camp Creek- Hoback Jct.

Draft Conceptual Mitigation Suggestion

US Hwy 189/191, Hoback - Camp Creek

Situation

- High concentration of elk-vehicle collisions.
- Important movement/migration area for mule deer and elk.
- Bighorn sheep licking road salt is a concern.
- 2, lanes, low traffic volume (1,600 vehicles/day), high percentage of semi-trucks.
- Relatively flat terrain immediately adjacent to road.

Draft Suggestions

- Wildlife fences and wildlife crossing structures are preferred (typically more reliable, effective and less risky than detection systems). However, the low traffic volume may allow for experiments with at-grade crossing opportunities.
- Consider wildlife overpasses (primarily based on the requirements for elk).
- Provide multiple crossing locations (perhaps one per mile or so).
- Keep large mammals from entering US Hwy 189/191 and reduce collisions through wildlife fences.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
- Livestock fences may be required at crossing structures to keep livestock on designated parcels. Consider using wildlife friendly livestock fences.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 39. Conceptual mitigation suggestion Rank 3, Section 1, Camp Creek- Hoback Jct.

Draft Conceptual Mitigation Suggestion

US Hwy 26/89/191, South of Jackson

Situation

- Very high mule deer and high elk-vehicle collision area.
- Important winter habitat for mule deer on both sides highway.
- Important mule deer migration corridor.
- Traffic volume about 9,000 vehicles/day

Draft Suggestions

- Provide a safe wildlife (mule deer, elk) crossing opportunity through a wildlife overpass. Note: to minimize human-livestock-wildlife conflicts, the overpass may be "closed" at certain times of the year.
- Have the overpass potentially become a more important element in mule deer migration corridor as the highway and the town of Jackson increasingly block the mule deer movements across the highway at the base of High School Butte.
- Keep large mammals from entering the highway through wildlife fences.
- Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 40. Conceptual mitigation suggestion Rank 4, Section 3, US Hwy 26/89/191 South Park Loop (south end) - Jackson.

Draft Conceptual Mitigation Suggestion

US Hwy 26/89/191, Broadway, Karns Meadow Park

Situation

- Highest concentration of large mammal-vehicle collisions in Teton County.
- 5 lanes, very high traffic volume (multiple tens of thousands of vehicles per day)
- Important winter habitat for mule deer on both sides Broadway.
- Important mule deer migration corridor is bisected by Broadway.
- Flat Creek bridge is not suitable and cannot be made suitable for large mammals.

Draft Suggestions

- Connect East Gros Ventre Butte with the habitat (Karns Meadow Park) and mule deer migration corridor (Flat Creek Corridor/Snow King) through a wildlife crossing structure; a wildlife overpass.
- Keep large mammals from entering Broadway and reduce collisions through wildlife fences (north side Broadway) and limited wildlife fences and retaining walls (south side Broadway)
- Mitigate access roads with electric mat or electric concrete.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
- Implement better highway lighting to improve visibility of mule deer and other large mammals to drivers and perhaps discourage large mammals from crossing Broadway at-grade. Note: light is directed down towards road surface, minimizing light pollution.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 41. Conceptual mitigation suggestion Rank 4, Section 4, US Hwy 26/89/191 Karns Meadow Park in Jackson.

Draft Conceptual Mitigation Suggestion

WY 390 North of Jct with WY 22

Situation

- Very high moose-vehicle collision area.
- Important moose habitat on both sides highway.
- Traffic volume about 10,000 vehicles per day.

.

Draft Suggestions

- Provide a safe wildlife (moose) crossing opportunity and connect riparian habitat and floodplain along both sides of WY 390 through a bottomless structure (e.g. a bridge or a bottomless culvert), and provide a suitable dry path for large mammals under the road (path at least 8 ft wide, at least 15 ft high clearance above path).
- Make the structure (bridge or culvert) as wide as possible (e.g. minimum 30 ft wide, preferably 60-90 ft wide).
- Keep large mammals from entering WY 390 for the first 0.2-0.3 mi north of the junction through wildlife fences placed low on road bed so that the fence does not block vistas.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.
- Incorporate electric mats or electric concrete at fence ends.
- Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete.
- Alternatively, replace current bike/pedestrian box culvert with a bridge or large culvert that allows for multiple use by humans as well as wildlife, specifically moose. Pay attention to minimizing potential wildlife-human conflicts along the bike/pedestrian path.
- Keep the low posted speed limit (45 MPH day, 35 MPH night) in place.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 42. Conceptual mitigation suggestion Rank 5, Section 7, WY 390, Jct WY 22 – N Lilly Lake Lane.

Draft Conceptual Mitigation Suggestion

US Hwy 89/26 Dog Creek – Hoback elk feed ground area

Situation

- High concentration of mule deer and elk-vehicle collisions.
- Important movement/migration area for mule deer and elk.
- 2, lanes, low traffic volume (4,000-5,000/day).
- Relatively flat terrain immediately adjacent to road.

Draft Suggestions

- Wildlife fences and wildlife crossing structures are preferred (typically more reliable, effective and less risky than detection systems). However, the low traffic volume may allow for experiments with at-grade crossing opportunities.
- Consider at-grade crossing opportunities that are lighted when a vehicle approaches. This is aimed at improving visibility of large mammals to drivers in selected crossing locations and at hazing the animals off the highway when traffic approaches.
- Provide multiple crossing locations (perhaps one per mile or so).
- Keep large mammals from entering Hwy 189/191 and reduce collisions through wildlife fences.
- Encourage wildlife to cross the highway and keep them from entering the fenced road corridor through electric mats or electric concrete embedded in the travel lanes at the crossing areas.
- When a vehicle is detected (induction loops) approaching a crossing area, activate signs that inform the driver they are approaching a crossing area and advertise a lower speed (35 MPH). At the end of the crossing area have a sign that says "End Wildlife Crossing Area). When no traffic is present, the signs do not display any information (black).
- The lights at the crossing area are only "on" when a vehicle approached. The lights are directed down towards road surface, minimizing light pollution.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 43. Conceptual mitigation suggestion Rank 6, Section 2, US Hwy 26/89, Dog Creek – Hoback elk feed ground area.

Draft Conceptual Mitigation Suggestion

US Hwy 26/89/191, North of Jackson, Fish hatchery area

Situation

- High collision area for elk, also mule deer.
- Important elk migration corridor, in the past also bighorn sheep.
- Important winter habitat for elk on east side of highway (National Elk Refuge).
- A fence with jump-outs (west to east passage only) on east side highway (not on west side).
- High traffic volume (about 8,000-9,000 vehicles/day).
- Speed limit varies between 45-55 mi/h between different road sections and between day and night.

Draft Suggestions

- Provide a safe wildlife (elk) crossing opportunity through a wildlife overpass. Note: to minimize human-livestock-wildlife conflicts, the overpass may be "closed" at certain times of the year or they may be one-way only.
- Keep large mammals from entering the highway through wildlife fences on both sides of the highway.
- Create an approach to the overpass on the east side that is as gradual as possible (10-15 degrees maximum). This may require the slope extending onto the National Elk Refuge.
- Mitigate access roads with gates, wildlife guards, or electric mat or electric concrete.
- Incorporate wildlife jump-outs allowing large mammals to escape the road corridor.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 44. Conceptual mitigation suggestion Rank 7, Section 4, US Hwy 26/89/191, Fish Hatchery area.

Draft Conceptual Mitigation Suggestion

WY 22 Near Weigh Station

Situation

- Relatively high concentration of moose-vehicle collisions.
- Important movement/migration area for moose and rare carnivores.
- Steep terrain
- 2, lanes, relatively low traffic volume (5,000-6,000 vehicles/day).

Draft Suggestions

- Wildlife fences and wildlife crossing structures are preferred (typically more reliable, effective and less risky than detection systems). However, the low traffic volume may allow for experiments with at-grade crossing opportunities. Note: the current traffic volume is about the maximum you would want for an at-grade crossing.
- Consider at-grade crossing opportunities that are lighted when a vehicle approaches. This is aimed at improving visibility of large mammals to drivers in selected crossing locations and at hazing the animals off the highway when traffic approaches.
- Though highest priority road section is only 1 mile long, fence at least 3 miles to reliably reduce collisions by 80-100%.
- Provide multiple crossing locations (perhaps one per mile or so).
- Keep large mammals from entering the highway and reduce collisions through wildlife fences.
- Encourage wildlife to cross the highway and keep them from entering the fenced road corridor through electric mats or electric concrete embedded in the travel lanes at the crossing areas.
- When a vehicle is detected (induction loops) approaching a crossing area, activate signs that inform the driver they are approaching a crossing area and advertise a lower speed (35 MPH). At the end of the crossing area have a sign that says “End Wildlife Crossing Area). When no traffic is present, the signs do not display any information (black).
- The lights at the crossing area are only “on” when a vehicle approached. The lights are directed down towards road surface, minimizing light pollution.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 45. Conceptual mitigation suggestion Rank 9, Section 6, WY 22, Weigh Station Area.

Draft Conceptual Mitigation Suggestion

WY 22 Near Weigh Station

Situation

- Relatively high concentration of moose-vehicle collisions.
- Important movement/migration area for moose and rare carnivores.
- Steep terrain
- 2, lanes, relatively low traffic volume (5,000-6,000 vehicles/day).

Draft Suggestions

- Wildlife fences and wildlife crossing structures are preferred (typically more reliable, effective and less risky than detection systems). However, the low traffic volume may allow for experiments with at-grade crossing opportunities. Note: the current traffic volume is about the maximum you would want for an at-grade crossing.
- Keep large mammals from entering the highway and reduce collisions through wildlife fences.
- Though highest priority road section is only 1 mile long, fence at least 3 miles to reliably reduce collisions by 80-100%.
- Provide multiple crossing locations (perhaps one per mile or so).
- Encourage wildlife to cross the highway and keep them from entering the fenced road corridor through electric mats or electric concrete embedded in the travel lanes at the crossing areas.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 46. Conceptual mitigation suggestion Rank 9, Section 6, WY 22, Weigh Station Area.

Draft Conceptual Mitigation Suggestion

WY 390 Wilderness Dr. – Snake River Ranch Rd

Situation
- Not a high collision area.
- Important movement and migration area for mule deer and moose.
- Many side roads and drive ways.
- Limited sight distance due to curves and vegetation.
- Low day (45 mi/h) and night time speed limit (35 mi/h).

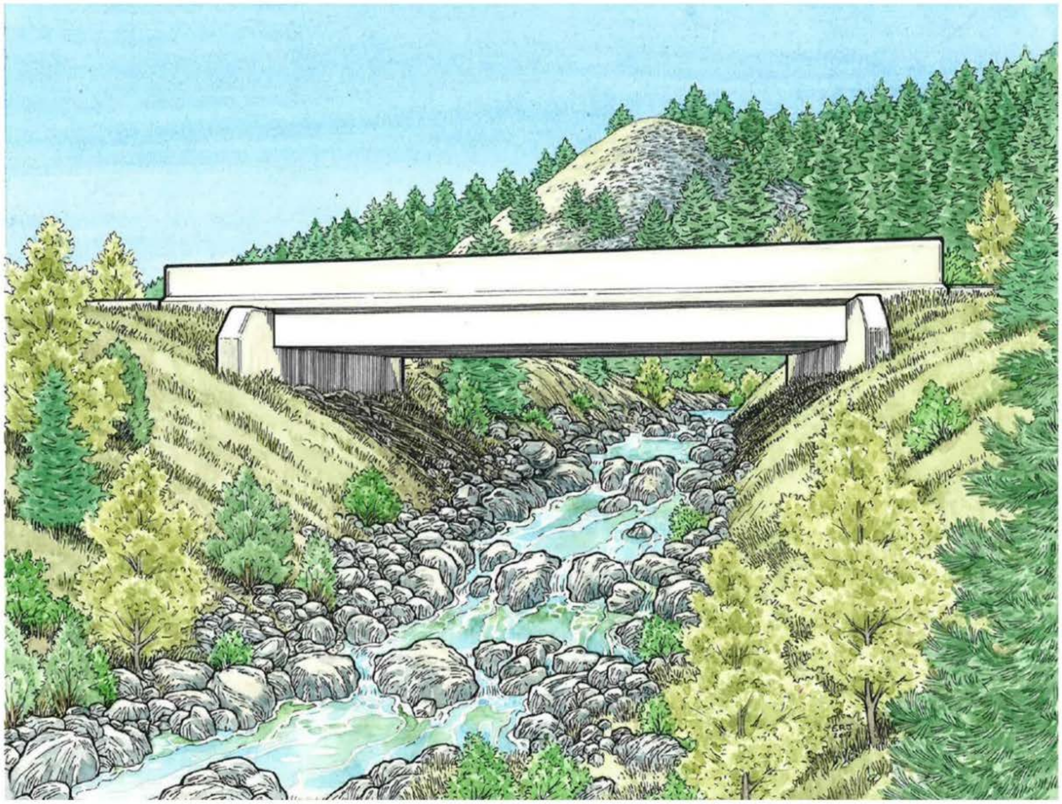
Draft Suggestions
- Keep the current speed limit (45 mi/h during the day, 35 mi/h during the night) in place.
- Monitor road mortality and the barrier effect. Should they substantially increase, consider additional mitigation measures.

Note: This is a suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 47. Conceptual mitigation suggestion Rank 10, Section 7, WY 390, Wilderness Dr. – Snake River Ranch Rd.

Draft Conceptual Mitigation Suggestion

US Hwy 26/89, Cabin Creek



Situation

- Steep gradient, high water volume and velocity.
- Substantial erosion downstream, failure of bank stabilization measures.

Draft Suggestions

- Provide a wider structure, spanning full bank width, allow for some dynamics in position stream.
- Mimic the upstream gradient, substrate (large boulders) and meandering.
- Through substrate and meandering mimic natural variations in water depth and velocity.
- Stabilize bank down stream, consider rerouting the stream to its original channel (once water velocity at outflow has been reduced).

Note: This is a draft suggestion. It illustrates the design principles and design concepts. This is not an official planning or zoning document. In addition, the suggestions are not necessarily tied to a specific parcel, but they do relate to recognizable road sections.

Figure 48. Conceptual mitigation suggestion No rank for terrestrial wildlife, based on aquatic connectivity only, Section 2, US Hwy 26/89, Cabin Creek.

7. PUBLIC MEETING

Teton County organized a public meeting on Wednesday July 19th 2017, 4-7 pm at the Teton County Library auditorium, 125 Virginian Lane, Jackson, Wyoming. Posters illustrating the problems with wildlife and highways and streams and highways and potential solutions were displayed in the meeting room (selected mitigation examples in chapter 6). Dr. Marcel Huijser provided a podium presentation on wildlife and highways. There was a question and answer session with the public after the presentation. In addition, the public was asked to provide written comments on the posters, including the draft mitigation measures (Appendix J).

While the detailed comments are included in Appendix J, the researchers would like to highlight the following:

1. Coordinating with landowners and land managing agencies for lands adjacent to the transportation corridors is required. Note that not all land owners may be supportive of mitigation measures, particularly not safe wildlife crossing opportunities. On the other hand, there are also landowners who have stated that they will grant an easement for certain crossing structures on or adjacent to their land.
2. Reduction in posted speed limit and wildlife warning signs were suggested by several people. Note that wildlife warning signs that are not specific in time or place are not effective in reducing collisions. Also note that speed management is complex, that a posted speed limit cannot be much below the design speed, and that the operating speed of vehicles needs to be less than 45 mi/h to allow about half the drivers to stop in time at night should there be an animal on the highway (see Chapter 2).
3. The conceptual drawings of suggested mitigation measures were largely supported by attendees at the public meeting (Table 12).

Table 12: The support or opposition with regard to the conceptual drawings of suggested mitigation measures (see also chapter 6 and Appendix J).

Aquatic/Terrestrial	Name	Section	Hwy	Supported "Yes" (green)	Not supported "No" (red)
Terrestrial	West of Camp Creek	1	191	13	2
Aquatic	Cabin Creek	2	89	5	0
Terrestrial	Rafter J	3	89	20	0
Terrestrial	Karns Meadow Park	4	89	27	1
Aquatic/Terrestrial	Spring creek	6	22	9	0
Aquatic/Terrestrial	Snake River	6	22	11	0
Terrestrial	Jct Hwy 22 and 390	6	22	22	0

8. EFFECTIVENESS OF WILDLIFE WARNING SIGNS AND REDUCED SPEED LIMIT ALONG WY 390

8.1. Introduction

This chapter is in response to some of the comments during the public meeting (see Chapter 7). The researchers investigated the effectiveness of reduced night time speed limit along the first 4 miles of WY 390 from the Jct with WY 22. This road section had the night time speed limit lowered from 45 mi/h to 35 mi/h in 2012. The daytime speed limit is 45 mi/h. There is a radar that displays the vehicle speed to the drivers, encouraging them to adhere to the speed limit. In addition, there is a variable message sign warning about moose-vehicle collisions, standard wildlife (moose) warning signs, and moose silhouettes places at the edge of the right-of-way by the private land owners.

8.2. Methods

The researchers applied a Before-After-Control-Impact (BACI) approach for the analyses. A BACI study design is a powerful study design for field studies. Here, it not only investigates the potential "Before-After" effect of the reduced night time speed limit on wildlife-vehicle collisions in the road section with the reduced night time speed limit (the "Impact" road section), but it also corrects for what may have happened independent of the implementing the night time speed limit reduction by including a "Control" road section. An example of another factor besides the night time speed limit reduction that could cause a reduction in collisions, is a potential reduction in the population size of large wild animals in the area after the night time speed limit was implemented. This potential reduction in population size could have happened because of other factors that have nothing to do with having implemented a night time speed limit reduction. Including a nearby control area in the same riparian habitat "Controls" for such potential other factors. Should an effect of the "Impact" (or "treatment; here the treatment is the night time speed limit reduction) be present, then the potential difference between Before and After should depend on the area (Control vs. Impact area). This is logical; the effect should only be present in the "Impact" area (or "treatment") and not in the "Control". If the potential difference between Before and After does not depend on the area ("Control" vs. "Impact" area), then it is an indication that there are other factors at play besides having implemented a reduced night time speed limit. Therefore, BACI analyses focus on the interaction between the Before-After variable and the Control-Impact variable.

Data from 1 January 2006 through 31 December 2011 were the "Before" data, and data from 1 January 2013 through 31 December 2016 were the "After" data (Note: the 2016 data were added to have the maximum sample size for the BACI analyses, but the identification and prioritization process in the previous chapters was based on data from 2006 through 2015). The data from 2012 were excluded from the analyses as this is the year the night time speed limit reduction was implemented and therefore the 2012 data partially related to the "Before" period and partially to the "After" period.

The “Impact” area was the road section with the reduced night time speed limit (WY 390 from mile reference post 0.0 (at the Jct with WY 22) through 4.0). The nearby section of WY 22 with similar habitat that also crossed through the Snake River Floodplain (mile reference post 3.0 through 5.0) served as the “Control”. For the most part this road section had a speed limit of 45 mi/h (day and night). Note that WY 22 also had various wildlife warning signs.

The researchers used four different datasets, each with their own BACI analysis:

- Large mammal crash data, collected by law enforcement personnel. The records related to deer, elk, moose, and “species not recorded”. Since the crashes were serious enough (vehicle damage, potential human injuries or human fatalities) to be included in the crash database, the researchers assumed that the “species not recorded” were also large mammals, predominantly large ungulates. This data is considered to have consistent search and reporting effort.
- Carcass removal data collected by road maintenance personnel from WYDOT. These data related to large mammals only; deer, elk, and moose. This data is considered to have consistent search and reporting effort.
- The JHNM/JHWF large mammal collision data (combination of all sources). This data is considered to have less consistent search and reporting effort compared to the crash and carcass data (the first two data sets) because of the incidental observations. On the other hand, this data is the most complete as it combines observations from all sources.
- The JHNM/JHWF moose carcass observation data (combination of all sources). Same as above, but the researchers only selected moose carcasses for this dataset.

For each of the four datasets, the researchers calculated the average number of collisions or carcasses per calendar year (6 years with “Before” data and 4 years with “After” data), and then calculated the averages and associated standard deviations for the “Before” and “After” years in both the” Control” road section and the road section with reduced night time speed limit (the “Impact” road section). The averages and standard deviations were plotted in graphs.

The researchers proceeded by conducting an Analysis of Variance (ANOVA) based on the transformed collision and carcass data (Ln(x+0.1)). This transformation was required to make the “count” variable resemble a normal distribution which is a requirement for an ANOVA. The researchers investigated whether the interaction between the Before_After parameter and the Control_Impact parameter was significant. A significant interaction suggests an effect of the “Impact” (or “treatment”; i.e. the night time speed limit reduction) whereas the absence of a significant interaction suggests that there is no effect of the “Impact”.

8.3. Results

For all four datasets, the averages and standard deviations for the “before” and “after” years in both the control road section and the road section with reduced night time speed limit were plotted in graphs (Figures 49 through 52). In general, when the line for the control road section and the line for the road section with reduced night time speed limit have different trends between “before” and “after”, it is an indication that there may be an effect of the treatment (i.e. the reduced night time speed limit). Parallel lines are an indication that there is no effect of the treatment. The vertical lines in the graphs represent the standard deviations. Greater standard deviations indicate greater variability in observed crashes, carcasses or collisions among the individual years.

The ANOVAs for the four datasets did not show a significant interaction between the Before_After parameter and the Control_Impact parameter (WYDOT crash data: $F_{(1,16)} = 0.60$, P=0.449; WYDOT carcass removal data: $F_{(1,16)}=0.32$, P=0.147; JHNM/JHWF large mammal WVC data: $F_{(1,16)} = 1.49$, P=0.239); JHNM/JHWF Moose WVC data: $F_{(1,16)} = 1.32$, P=0.267).

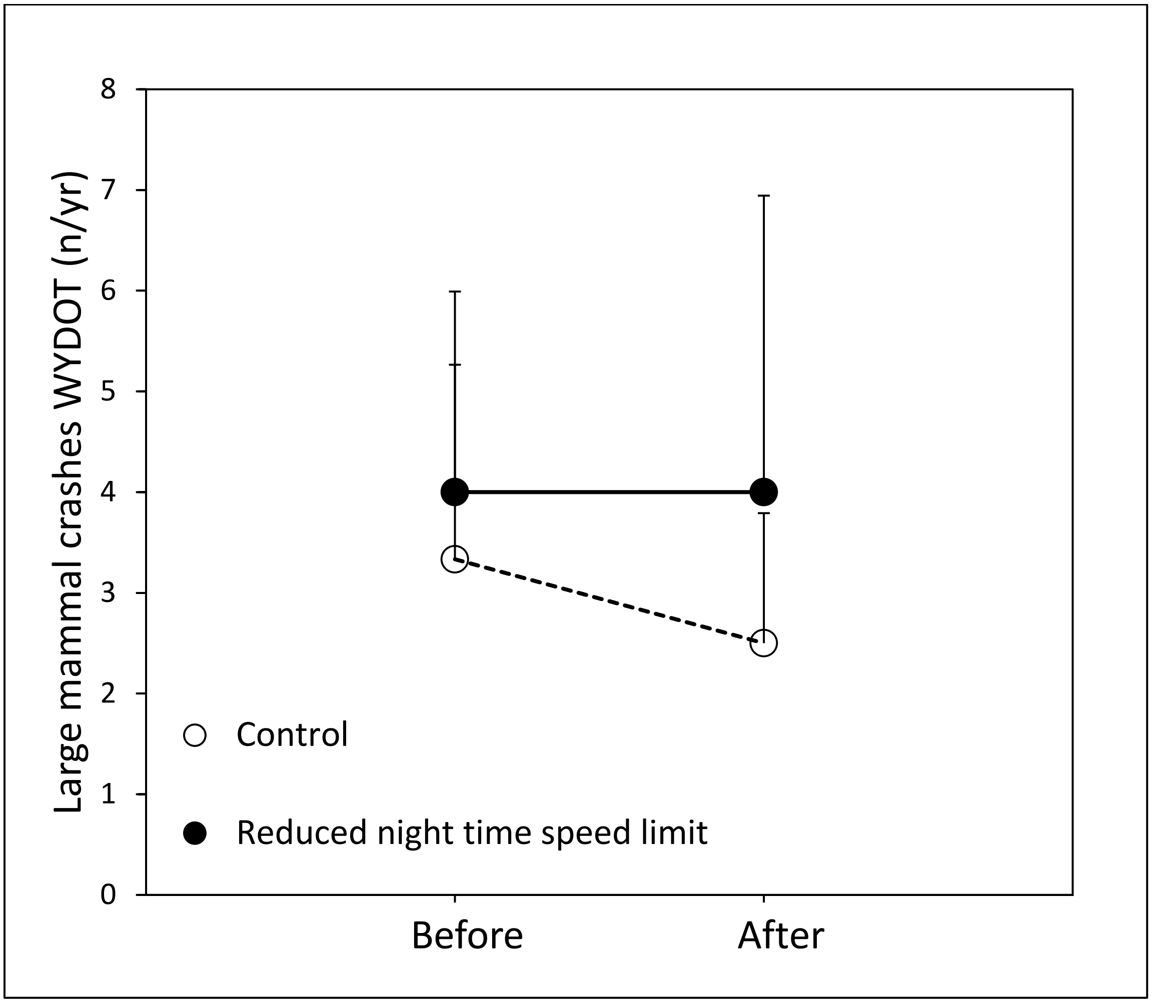


Figure 49. The average number (and associated standard deviation) of large mammal crashes "before" and "after" in both the control road section and the road section with reduced night time speed limit.

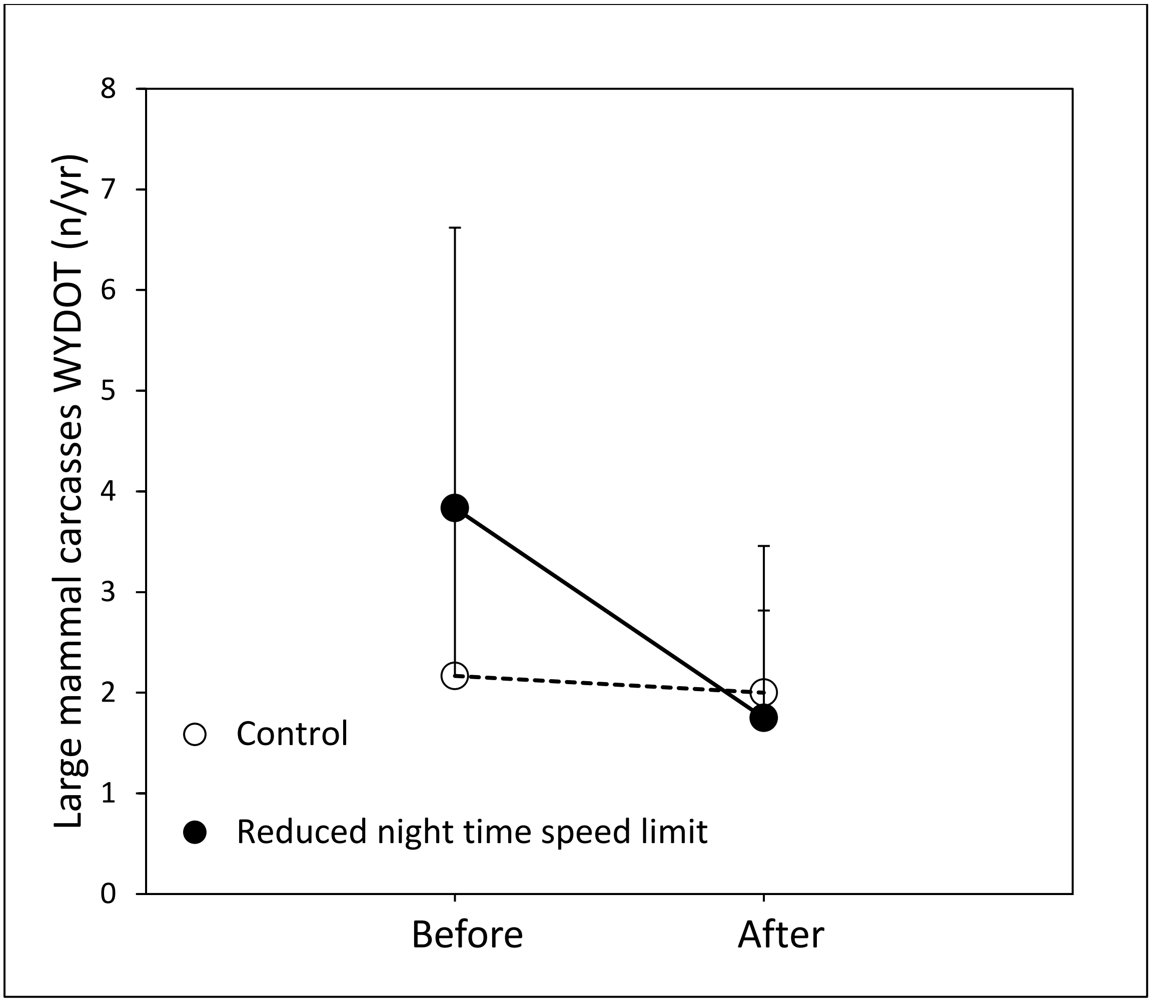


Figure 50. The average number (and associated standard deviation) of large mammal carcasses "before" and "after" in both the control road section and the road section with reduced night time speed limit.

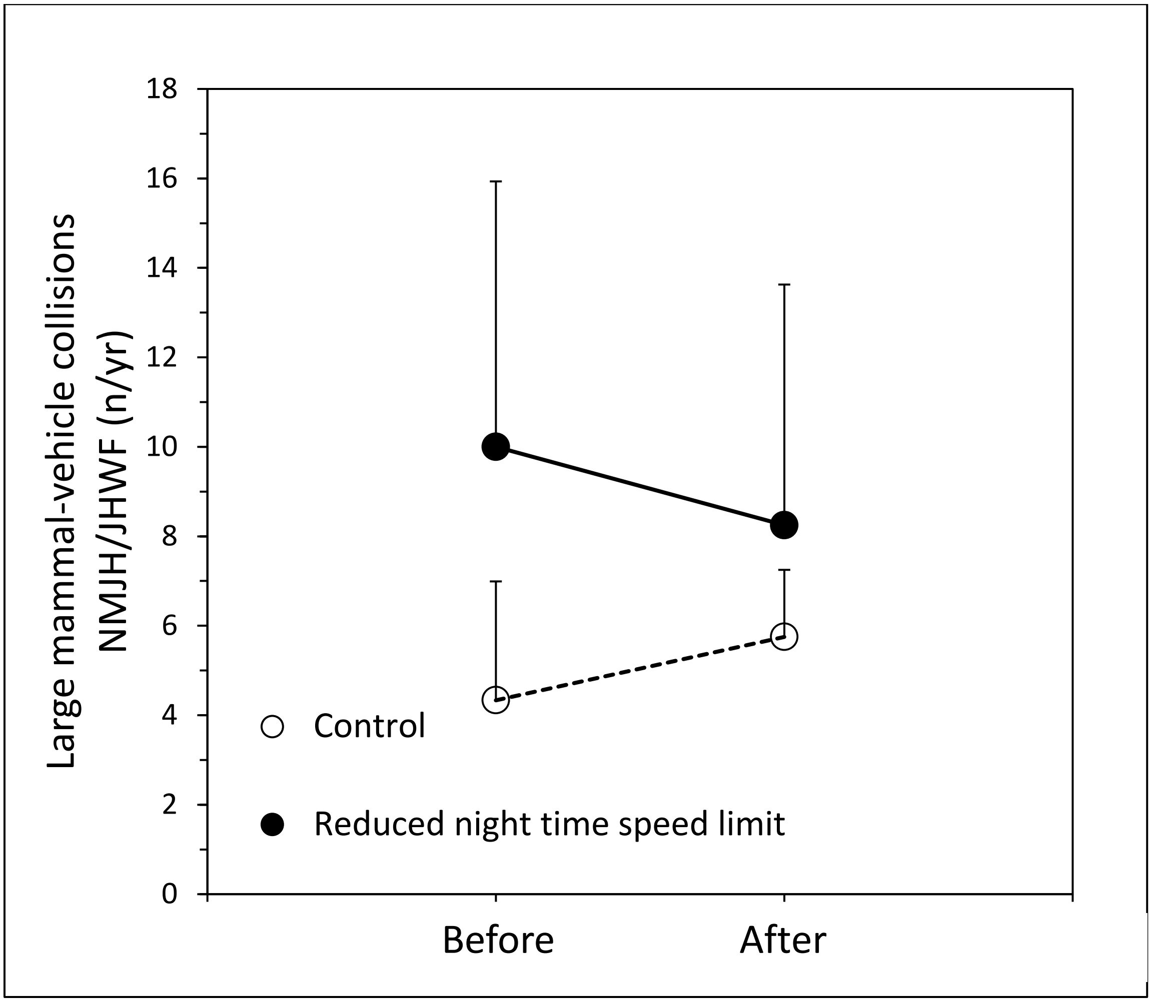


Figure 51. The average number (and associated standard deviation) of large mammal-vehicle collisions (combination of sources) "before" and "after" in both the control road section and the road section with reduced night time speed limit.

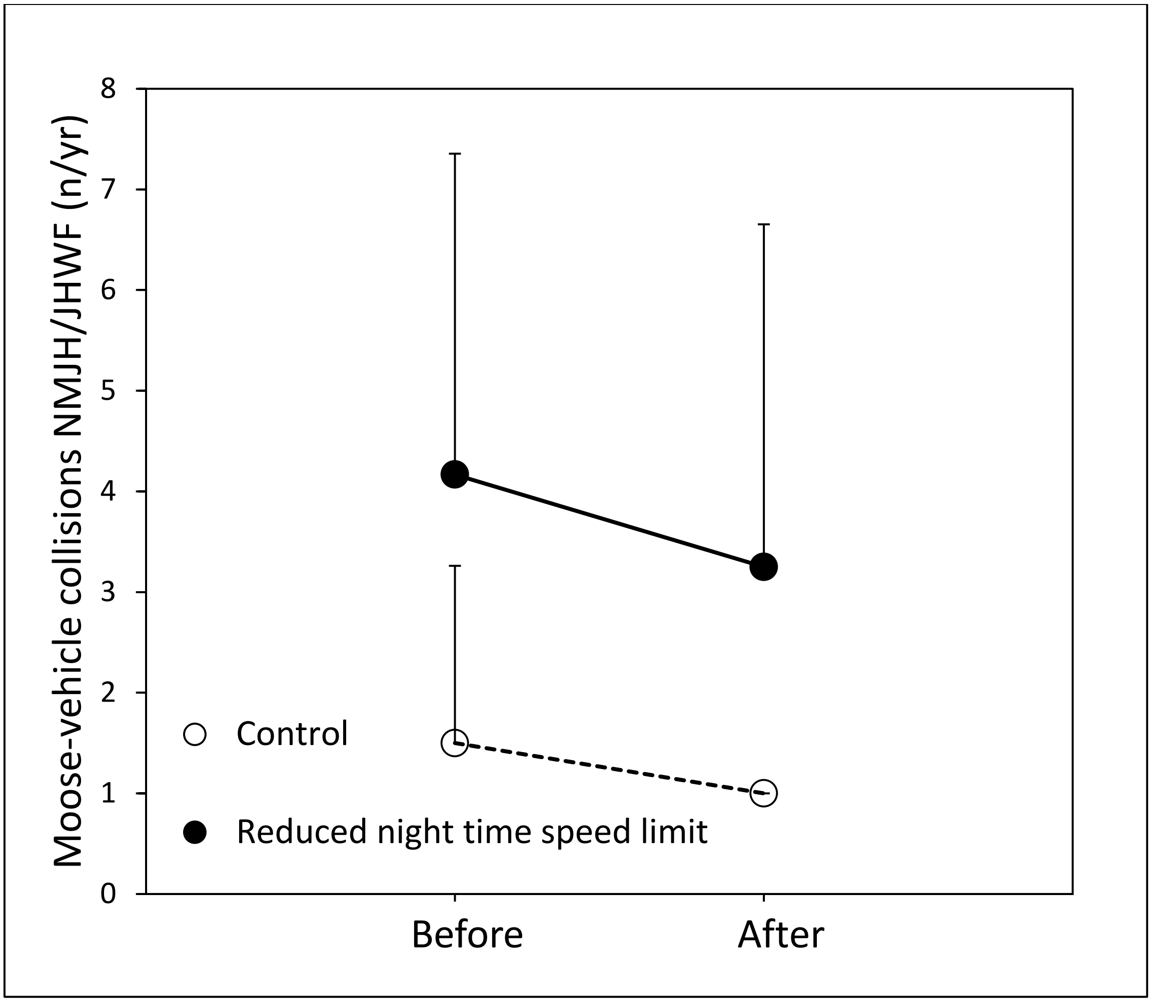


Figure 52. The average number (and associated standard deviation) of moose-vehicle collisions (combination of sources) "before" and "after" in both the control road section and the road section with reduced night time speed limit.

8.4. Conclusion

The results of the analyses suggest that there is no statistical evidence that the mitigation measures (i.e. reduction in night time speed limit and wildlife warning signs) have resulted in fewer collisions with large wild mammals or moose. However, it is always possible there is an effect present but that more data (i.e. more years with "after" data) are needed to detect the effect and reach statistical significance. However, based on the current averages, only two of the four datasets suggest there could potentially be an effect (WYDOT carcasses and JHNM/JHWF large mammal WVC data) whereas the other two data sets do not show any indication of a possible effect (WYDOT crash data and JHNM/JHWF moose WVC data). Combined with the relatively great standard deviations, it is unlikely that adding one or a few years of data will show a significant effect, should there indeed be a significant effect.

While there currently is no detectable benefit of the night time speed limit reduction along WY 390, it would be wrong to conclude that vehicle speed is not an important factor for wildlife-vehicle collisions. Higher vehicle speeds clearly result in longer stopping distance (see Chapter 2). For speed management to be substantially effective as a measure to potentially reduce collisions with large mammals for more than half the drivers, the design speed, mandatory speed limit, and actual operating speed of the vehicles may need to be 35-40 miles per hour at a maximum (Chapter 2; Huijser et al., 2015a; Huijser et al., 2017). In this chapter we only showed that reducing an already low posted speed limit (45 mi/h) to an even lower speed limit (35 mi/h) did not result in a significant reduction in collisions with large wild animals. However, based on the graph in Chapter 2, it is likely that collisions would increase with higher vehicle speed. Therefore, keeping the speed limits low along WY 390 is a good idea. The design speed of WY 390 is low as it is (especially in the curvy southern section with limited sight distances). Therefore, the current posted speed limit (45 mi/h during the day, 35 mi/h during the night) is unlikely to result in speed dispersion and an overall increase in crashes (see Chapter 2). But if such low posted speed limits would be implemented on highways with a much higher design speed, overall human safety may be negatively affected (see Chapter 2). In summary, reducing posted speed limits to the 35-45 mi/h range likely has benefits for reducing wildlife-vehicle collisions, but such low posted speed limits can only be implemented along highways that have a corresponding low design speed. In general, reducing posted speed limits substantially below the design speeds of highways is potentially dangerous to human safety and should be avoided. Speed management as a tool to reduce wildlife-vehicle collisions is limited to roads with a low design speed.

9. MONITORING RECOMMENDATIONS

9.1. Research questions

Monitoring of wildlife mitigation measures is typically tied to the following types of questions:

1. Do the mitigation measures improve human safety through a reduction in collisions with large wild mammals? This is a testable question.
2. Do wildlife species use the safe crossing opportunities sufficiently? This question is not formulated in a testable manner. A more precise formulation is required in order to conclude whether the safe crossing opportunities are "effective" (see section 9.3).

9.2. Reduction in Wildlife-Vehicle Collisions

One of the strongest study designs for a field study is a Before-After-Control-Impact (BACI) approach (van der Grift et al., 2013; Rytwinski et al., 2015; 2016). It involves collecting data on wildlife-vehicle collisions both "before" and "after" the mitigation measures were implemented. In addition, these data are not only collected along the road sections that were mitigated ("impacted"). They are also collected along "control" road sections that were not mitigated. This is important because the abundance of large mammals can fluctuate widely from year to year, so simple "before" and "after" measures of carcasses may reflect changes in the number of animals in the population rather than the effects of the mitigation. In general, more data (longer time periods, more locations) result in greater "statistical power" that makes it more likely to detect a change associated with the implementation of the mitigation measures, should there indeed be such an effect.

In summary:

1. Select appropriate mitigation and control sites (potentially random, potentially pairs with similar conditions other than the absence or presence of the mitigation measures). Note that "zero" observations negatively affect the ability to draw conclusions on the effectiveness of the mitigation measures. Thus, the road sections should be long enough to avoid the occurrence of "zero" observations of wildlife-vehicle collisions.
2. Have sufficient site replication. In general, the more mitigation sites and the more control sites, the better. Most statistical analyses require at least 3 to 5 replicates (sets of control and mitigation sites).
3. Select the appropriate period during which data are collected, and decide on the number of periods before and after implementation of the mitigation measures. Since there is a strong seasonal influence on the number of wildlife-vehicle collisions, the sample unit is typically one full calendar year, and there are typically at a minimum 2 years with "before" data and, at a minimum, another 2 years with "after" data (Rytwinski et al., 2016).
4. Make sure the data are collected with similar search and reporting effort before and after the implementation of the mitigation measures. It is not essential that all collisions (or crashes or carcasses) are recorded, but inconsistent search and reporting effort may make

the analyses meaningless. Data collection by law enforcement and carcass removal data by road maintenance personnel typically meet the basic requirements of consistent search and reporting effort. While incidental observations by other entities (e.g. natural resource management agencies) or the public can be very valuable to answer some questions, the search and reporting effort in time and space is usually not consistent (but see Paul et al., 2013 as an illustration of an exception).

5. Consult researchers before initiating a research project to assist in the finalization of the data collection program.

9.3. Wildlife Use of Safe Crossing Opportunities

For this report, safe crossing opportunities mean either crossing structures (underpasses and overpasses) or at grade-crossing opportunities (stand-alone animal detection system, animal detection (or vehicle-detection) system at a gap in a wildlife fence.

Most studies that evaluated wildlife use of safe crossing opportunities simply tally how many individuals of what species use the crossing opportunities over a certain period (van der Grift et al., 2013). While such data may illustrate “substantial use” it does not necessarily provide us with insight on the effectiveness of the safe crossing opportunities, as “effectiveness” needs to be tied to an objective. Therefore, it is essential that objectives are formulated before the data collection is initiated. There can be multiple research questions associated with different ambition levels, and each would have their own associated research methods (see also van der Grift et al., 2013).

For example:

1. Do certain target species use the safe crossing opportunities? The research activities can be designed towards either detecting or not detecting successful use of the safe crossing opportunities by the target species.
2. How many individuals of certain target species use the crossing structures? The research activities can be designed towards counting the number of individuals that successfully use the safe crossing opportunity.
3. Are the safe crossing opportunities suitable for the target species? The research activities can be designed towards detecting the target species as they approach the safe crossing opportunity and then evaluate whether they “accept” or “reject” the safe crossing opportunity. Since the statistical population is the number of individuals (or number of groups) of animals that approach the crossing opportunity, the test parameter is independent of the population size or differences in population size between different locations and different crossing opportunities. Thus, this method allows for a direct comparison of the suitability of different types and dimensions of safe crossing opportunities (e.g. Purdum, 2013; Sawyer et al., 2012).
4. Do the mitigation measures result in improved or reduced connectivity? After wildlife fences are implemented the animals can no longer cross the highways anywhere; they can only cross at the locations of the safe crossing opportunities. The research activities can be designed towards comparing connectivity “before” and “after” the implementation of the mitigation measures. The “before” connectivity would be based on successful at-

grade highway crossings while the "after" connectivity would be based on successful crossings through or over the crossing structures or successful at-grade crossings at gaps in the wildlife fence. This is a research method that includes a "reference" and it is testable whether the "after" situation is similar, worse, or better than the "before" situation (Huijser et al., 2016b). Note that there is a learning curve; some species learn about the location of the crossing opportunities and that it is safe to use them, and they increase their use of the structures as the structures have been in place for longer (Ford et al., 2010; Huijser et al., 2016b). This means that the number of successful crossings at the safe crossing opportunities depends on the age of the structures, and that in turn can change the conclusion of the research.

5. Do the safe crossing opportunities get used many times by a small percentage of the individuals, or do they get used regularly by many different individuals in the populations on either side of the highway? The research activities can be designed towards detecting individual animals both at the safe crossing opportunities as well as in the surroundings on both sides of the highway (e.g. Sawaya et al., 2013).
6. Do the mitigation measures allow for "gene flow" or genetic connectivity? The research activities can be designed towards detecting whether "genes" make it to the other side of the highway through individuals that "come" from one side of the highway, and "breed and have young" on the other side of the highway. If this happens often enough, there should be little or no difference in the frequency of certain alleles in the populations on either side of the highway. Note that it may take multiple or even many generations for barrier effects or improved connectivity to result in genetic differences or genetic similarity between the two sides of a highway.
7. Do the mitigation measures allow for successful seasonal migration by certain target species? The research activities can be designed towards comparing the migration routes, the number or percentage of successful highway crossings by migrating individuals, and potential lingering (staging, indicating hesitancy or difficulty) before crossing highways, both "before" and "after" the implementation of the mitigation measures (e.g. Seidler et al., 2015).
8. Do the mitigation measures contribute towards making the populations of certain target species more viable through reduced unnatural mortality and (improved) connectivity across highways? The research activities can be designed towards compiling existing data on population dynamics, habitat connectivity, use of the crossing structures (especially by animals that move over long distances and that can colonize or re-colonize far away areas (dispersal)), and then conduct modeling to evaluate the outcome of different scenarios (e.g. no mitigation vs. different packages of mitigation measures) on the population viability of the target species.
9. Do the mitigation measures, specifically the safe crossing opportunities, allow for ecosystem processes across the highways? The research activities can be designed towards measuring ecosystem processes. Ecosystem processes can be very broad. They may relate to animal movements, migration patterns, and population viability. However, ecosystem processes can also relate to other taxonomic groups (including invertebrates, plant species), as well as abiotic process in the soil, or ground or surface water.
10. Do the mitigation measures, specifically the safe crossing opportunities, allow for ecosystem processes across highways as plants, animals, and entire ecosystems may need to move in response to climate change? The research activities can be designed towards

measuring the movement of "ecosystems" or indicators of "ecosystems" and if and how they move across the landscape, both away from highways and across highways. This is a very complicated and long-term process.

Each of the objectives comes with its own research design and associated methods. However, wildlife use at or in the immediate vicinity of wildlife crossing structures is typically measured using wildlife cameras (e.g. Huijser et al., 2016b; Cramer and Hamlin, 2017). Tracking beds (e.g. strips of sand or other substrate put in place to detect animal tracks) are costlier (time, money) and less accurate, especially for species that move in groups and in large numbers (Ford et al., 2010, Huijser et al., 2016b). However, sometimes, when there is a need to monitor wildlife crossings over long road distances, it is not practical to use wildlife cameras, which only capture animals that pass in front of the camera at short range (e.g. Huijser et al., 2016b; Riginos et al., 2015).

Acceptance or rejection of crossing structures by individual animals is typically measures by placing wildlife cameras at the entrances of crossing structures so that approaching animals trigger the camera; this allows us to evaluate whether they used the crossing structure successfully or turned back (Purdum, 2013). Individual animals within a species often cannot be told apart based on camera images. If one needs to be able to identify individuals and tell them apart from other individuals, DNA needs to be collected. Barbed wire has been used to collect hair samples at wildlife crossing structures and in the surrounding habitat (Sawyer et al, 2013). The DNA can be obtained from hair follicles.

Seasonal migration movements are best measured through GPS collars (e.g. Seidler et al., 2015). However, depending on the frequency at which a GPS location is obtained, one may not be able to tell whether and which safe crossing opportunity was used to access the other side of the highway. Therefore, the GPS collars may need to be supplemented by wildlife cameras at the safe crossing opportunities.

Population viability can be estimated through modeling based on existing data and a set of assumptions (van der Grift et al., 2013). However, one may also choose to use local data obtained through field research.

Recommendations:

1. Go through a step-wise process to identify and formulate the research questions and associated research methods with regard to safe crossing opportunities (van der Grift et al., 2013). Note that this may be an iterative process because of practical or budget limitations.
2. Formulate testable research questions. The results will be of greater use to informing future highway mitigation projects.
3. Consult researchers before initiating a research project to assist in the finalization of the research questions and associated methods.

10. MITIGATION FUNDING SOURCES

10.1. Introduction

There are a variety of potential sources of funding that support the reduction of wildlife-vehicle collisions (WVCs) and that provide for the maintenance or restoration of habitat connectivity in Teton County, Wyoming. These sources include a mix of traditional transportation programs, as authorized in the latest federal transportation act in 2015, the FAST Act (Fixing America's Surface Transportation *Act),* Public Law No. 114-94. This surface transportation reauthorization retained all of the transportation programs with wildlife provisions, except one, from the previous surface transportation bill, MAP-21 (Moving Ahead for Progress in the 21st Century Act), Public Law 112-141 (23 USC, §101 et seq.) MAP-21, for the first time ever, provided explicit language to use different transportation program funds to reduce WVCs and/or address habitat connectivity (Callahan and Ament, 2012).

The FAST Act also re-authorized a key program that allows state departments of transportation (DOTs) to develop programmatic mitigation plans for species, geographical areas, habitat types or other foci at a broad scale. This new provision for large landscape mitigation plans, instead of using the more standard "project by project" approach, could be explored by Teton County (County) with the Wyoming Department of Transportation (WYDOT) for federal and state highway mitigation within the County. That is, if WYDOT would be willing, they could consider Teton County a geographic area under this program and incorporate the findings of the Teton County Master Plan into its state transportation plan.

There are many other potential funding sources, besides federal-state transportation programs, for wildlife crossings within Teton County that improve the prospects of deploying a series of high priority wildlife crossing projects. Funding partnerships can be forged by the County given the fact that reducing WVCs can provide additional benefits beyond those provided for improving motorist safety. Partners may be interested in co-funding wildlife crossing projects for the collateral benefits to wildlife conservation, the protection of threatened or endangered species, improved habitat and ecological connectivity resulting from highway mitigation infrastructure (i.e., wildlife underpasses, fish passage), or reduced costs of collisions (injuries, property damage, fatalities) to local taxpayers and visitors, alike. A variety of interests is often useful to leverage traditional transportation funding with funding from non-transportation agency funds or with interested non-transportation partners. Such benefits reach well beyond the realm of transportation safety, providing the County with the opportunity to develop new partnerships that tap the resources of non-transportation partners.

To generate the greatest variety of funding opportunities, partnerships for wildlife crossing projects may require a mix of the County's funds with federal, state, and local agencies as well as non-profit organizations, philanthropic foundations and/or individuals. This is because there are many different grant programs that could be tapped for highway mitigation and because there are restrictions that often apply on the type of recipients that can receive funding from corporate and private philanthropy. A mix of County, federal, state, local, private individuals and/or non-profit organizations working together will help maximize the sources of funding that can be utilized to implement the priorities set in the Teton County Wildlife Crossing Master Plan.

Below are some of the potential federal and state funding sources that might be available for wildlife crossing projects in Teton County. Many of the different categories could be more readily accessed if multi-stakeholder partnerships are developed for WVC mitigation projects and their implementation, monitoring, research and outreach.

10.2. State and National Transportation Funding Sources

The FAST Act authorizes the funding of a variety of surface transportation programs for federal fiscal years 2015 through 2019. It is a remarkable transportation law that explicitly defines as one of its targets the reduction in the number of motorist collisions with wildlife. Some programs also describe projects eligible for funds including those that improve connectivity among habitat disrupted by roads. These provisions are incorporated into various programs for state, federal, and tribal agencies (Callahan and Ament 2012).

10.2.1. Wyoming Department of Transportation Programs and Funds

Surface Transportation Block Grant Program (STP) *(23 U.S.C. § 133(b)(15)).*
Eligible projects under the STP include activities to reduce vehicle-caused wildlife mortality or to restore and maintain connectivity among terrestrial or aquatic habitats.

Highway Safety Improvement Program (HSIP) *(23 U.S.C. § 148)*
Eligible highway safety improvement projects include the addition or retrofitting of structures or other measures to eliminate or reduce crashes involving vehicles and wildlife. These funds are typically allocated based on crash rate and crash severity prioritization through cost-benefit analysis. Therefore, wildlife crossing sites that have high rates of WVCs would be competing with all other crash types for funding.

10.2.2. BUILD replaces TIGER Discretionary Grants

Originally Transportation Investment Generating Economic Recovery (TIGER) grants were administered by the FHWA as part of the American Recovery and Reinvestment Act of 2009 (the "Recovery Act"). They were competitive grants that could be awarded directly to state, county or city governments for surface transportation projects. The granting program under the Recovery Act was completed in 2012. Since then TIGER grants have continued to be awarded in Fiscal Years 2013-2016. Altogether the TIGER grant program has awarded $5.1 Billion and have averaged a co-investment of $3.60 per TIGER dollar (USDOT 2017, online at: https://www.transportation.gov/tiger [accessed 5 October 2017]). On 7 September 2017, Secretary of Transportation, Elaine L. Chao, announced another year of TIGER funding is available with $500M for national infrastructure investments, and a minimum of $1M was set for individual rural grants.

In April of 2018, Secretary Chao announced that the USDOT would replace TIGER with Better Utilizing Investments to Leverage Development (BUILD) discretionary grants. BUILD is slated to provide $1.5 Billion to support roads, bridges, transit and other modes of surface transportation projects through September 2020, online at: www.transportation.gov/BUILDgrants/about [accessed 25 May 2018]. It is to increase its focus on rural America's transportation infrastructure needs. The funds will be dispersed so that no more than $150 Million can be allotted to any one state.

10.2.3. Eco-Logical Competitive Grants

Eco-Logical is the FHWA's ecosystem approach to consider and protect natural resources using an integrated approach to transportation planning and projects. In the past, there have been 15 grants totaling $1.4M provided to explore different facets of Eco-Logical. The needs for Eco-Logical research are incorporated in to the Strategic Highway Research Program (SHRP 2). Future SHRP 2 competitive grants may be sought by Teton County by partnering with WYDOT or federal land management agencies for wildlife crossing project implementation. SHRP 2 grants are primarily for funding projects designed to provide the tools needed to implement the Eco-Logical approach. The program has disbursed $130M for 60 projects (see program information online at: http://www.environment.fhwa.dot.gov/ecological/ImplementingEcoLogicalApproach/Grant_Program.asp [accessed 10 October 2017].

10.3. Federal Land Management Agency Transportation Programs

Since many of the roads in Teton County traverse through federal lands — National Forest, National Park, National Wildlife Refuge — it may choose to collaborate with local federal land management units to fund and implement wildlife crossings of mutual interest. The following programs' funds are directed to Teton County's potential federal land management agency partners or WYDOT, but the projects could be utilized to emphasize and potentially fund or co-fund the County's priority wildlife crossings.

10.3.1. Federal Lands Transportation Program (23 U.S.C. §§ 201-203)

Federal land management agencies have three transportation programs; one of these is the Tribal Transportation Program, which cannot be used in Teton County due to the lack of tribal roads. However, the Federal Lands Transportation Program and the Federal Lands Access Program could be tapped in partnership with federal land management agencies in the County. (see program information online at: http://www.dot.ca.gov/hq/transprog/map21/implementation/aashto_sum_fastact_121615v2.pdf [accessed 10 October 2017])

a.) Federal Lands Transportation Program (FLTP)

The FLTP helps improve multi-modal access within national parks, forests, wildlife refuges, Bureau of Land Management (BLM) lands, and U.S. Army Corps of Engineers (USACE) facilities. The FLTP funding is authorized at $335M for Fiscal Year (FY) 2016 and steadily increases through FY 2020 at $375 million under the Fast Act. The National Park Service gets the program's largest set aside at $268 M in the first year up to $300 M in FY 2020, receiving the majority of the program's funding. The US Fish and Wildlife Service is authorized to receive $30M each year, the US Forest Service is slated to receive $15m in FY 2016 increasing to $19M in FY 2020. The remaining funds are competitively apportioned to the Bureau of Land Management (BLM), Army Corps of Engineers and other federal agencies, depending on their needs (see program information online at: https://www.fhwa.dot.gov/fastact/factsheets/fedlandstransfs.cfm). [accessed 10 October 2017])

The FLTP focuses on the transportation infrastructure owned and maintained by Federal land management agencies. Funding from this program can be used to pay for environmental mitigation in, or adjacent to, federal land open to the public to improve public safety and reduce vehicle-caused wildlife mortality while maintaining habitat connectivity; or to mitigate damage to wildlife, aquatic organism passage, habitat, and ecosystem connectivity, including the costs of constructing, maintaining, replacing, or removing culverts and bridges. The FLTP would allow the County to cooperate with federal land management agencies on wildlife crossings of mutual interest.

b.) Federal Lands Access Program (FLAP)

The FLAP complements FLTP by providing funds to improve transportation facilities that provide access to, are adjacent to, or are located within federal lands. It has been authorized for funding at $250 M in FY 2016 up to $270M in FY 2020. FLAP supplements state and local resources for public roads, transit systems, and other transportation facilities, with an emphasis on high-use recreation sites and economic generators. Funding from this program can be used to pay for environmental mitigation in or adjacent to federal land to improve public safety and reduce vehicle-caused wildlife mortality while maintaining habitat connectivity. Again, many of the roads that would be prioritized for wildlife crossings in the County would be access roads to federal lands and can readily be shown to important economic generators, given the high levels of tourism in Teton County.

10.4. Programmatic Mitigation Plans (23 CFR § 169)

Although not a funding program for wildlife crossings, another interesting mitigation program first authorized under the MAP-21 Act and then continued under the FAST Act allows states and metropolitan planning organizations (MPOs) to develop programmatic mitigation plans as part of state-wide or metropolitan planning process. There is not an MPO in Teton County so this would be available only to WYDOT. Mitigation programs can be used to address potential future environmental consequences of transportation projects. It provides no funding authority to the states or MPOs to develop the mitigation plans. It allows such plans to be developed at a regional, ecosystem, watershed, or statewide scale. It does not preclude a programmatic mitigation plan from being a county-wide plan.

Few states or MPOs have taken advantage of this new authority since it was enacted in 2012. In addition, the Federal Highway Administration (FHWA) has provided only guidance (see online at: https://www.fhwa.dot.gov/map21/qandas/qaprogmitplans.cfm) to use this new provision so there has been no rulemaking to regulate how a DOT or MPO must develop and implement a programmatic mitigation program. However, it may be worthwhile for Teton County to determine if WYDOT would be interested in incorporating or adapting the County's wildlife crossings master plan into the state's first programmatic mitigation plan.

10.5. Wildlife Crossing Mitigation Credit System

Another state-based approach to wildlife crossing mitigation has been enacted by California via their advance mitigation program. They now have in place a system to create advance mitigation which allows for the development of a crediting system. It allows the California Department of Transportation to sell or transfer credits for a wildlife crossing it has just built to another future project within its own agency or to transfer them to other transportation agencies to potentially expedite future transportation projects. Teton County may seek to inquire with WYDOT if they would be interested in a similar type of wildlife crossing credit system for advanced mitigation (see online at: http://www.dot.ca.gov/paffairs/pr/2017/prs/17pr039.html [accessed 10 October 2017]).

10.6. Federal Non-Transportation Potential Funding Sources

The U.S Fish and Wildlife Service (USFWS) administers a variety of natural resource grant programs for state agencies. To employ these grant monies for County wildlife crossing projects, Teton County would have to work in cooperation with the Wyoming Game and Fish Department (WGFD) to seek funding for mutually agreeable projects for improved fish or wildlife passage. A cooperative highway mitigation project could have multiple benefits, such as improving motorist safety and conserving ungulate or non-ungulate species. Thus, priority wildlife crossing locations for the County may be areas where species protection is a priority of WGFD, making the project beneficial for both governments.

Following are examples of USFWS grants that could be made available for joint WGFD-Teton County wildlife crossing projects:

- Conservation Grants. This program provides funds to implement conservation projects for listed (as threatened or endangered under the Endangered Species Act (ESA)) and non-listed species.
- Cooperative Endangered Species Conservation Fund. This provides assistance for the conservation of listed, candidate or proposed species under the ESA.

10.7. Private Philanthropy

According to the National Philanthropic Trust, environmental and animal organization received the largest increase in giving, 7.8% from Americans in 2016 (online: https://www.nptrust.org/philanthropic-resources/charitable-giving-statistics [accessed 5 October 2017] That same year Americans gave over $389B, of which individuals gave the most ($282B), corporations ($18.5B) next, followed by foundations ($58B). Teton County residents have a long history of philanthropy, and support many efforts throughout the Jackson Hole area, including environmental and animal projects and programs.

Conserving wildlife and improving human safety have the potential to garner philanthropic support, particularly if County wildlife crossing projects are developed with a variety of components: construction, monitoring, research, education and/or community outreach. This is usually most successful when there are multiple partners involved in the project. Such a partnership can often benefit from having a non-profit organization (with Internal Revenue Service 501c3 status) that can receive tax deductible contributions for the project. While transportation infrastructure is generally financed through a combination of local, state or federal funding, private foundation philanthropy can increase funding efficiency by helping to leverage or match public funds for research, education, and outreach efforts. Most private philanthropy is focused on granting to non-profit organizations; therefore, for the County's wildlife crossings to benefit from philanthropy, it will be important to collaborate with non-profit organizations.

Although there are several examples of philanthropic foundations or individuals funding wildlife-highway projects in Teton County, one such case study will suffice. The non-profit organization, the Jackson Hole Wildlife Foundation (JHWF) developed a campaign coined “Give Wildlife a Brake®” to support the reduction of WVCs in Teton County. They organized WVC citizen data collectors and set up a web-based system to encourage recording carcasses along the County’s roads. Supported by donations from community members and foundations, JHWF bought 6 portable dynamic message signs (DMS) for WYDOT to deploy where wildlife-traffic conflicts occur (see Figure 53). JHWF and WYDOT have signed a Memorandum of Understanding to outline the terms of the use of the DMS. Each DMS cost approximately $16,000 each (personal communication, JHWF staff). JHWF also purchased two fixed radar signs that are deployed by WYDOT along a problematic WVC stretch of WY Highway 390 to let motorists know how fast they are traveling. This section of highway is programmed to reduce the posted speed from 45 mph to 35 mph from dusk to dawn. WYDOT's carcass removal data indicate that this mitigation effort could help reduce crashes with moose. JHWF has also bought two DMS for Grand Teton National Park for use on its roads where high incidences of wildlife and vehicular traffic occur.

Figure 53. Dynamic message sign on WY Highway 390. Photo: Rob Ament.

10.7.1. Corporate Philanthropy

American corporations have a long history of philanthropy and often give directly through their community programs (where their employees are located) or have created their own foundations. Depending on the company, they may also have employee contribution programs that they match. Other ways that corporations could support County wildlife crossing projects are to provide in-kind gifts or to provide volunteers for the projects. Priority wildlife crossing projects could be eligible to receive support from a variety of these corporate programs.

10.7.2. Organizations and Individuals

There may be many organizations and individuals that Teton County may find are eager to help build and maintain wildlife crossing projects. Some organizations may be more aligned than others, such as environmental, or fish and wildlife conservation groups. For example, a handful of conservation groups have a Memorandum of Understanding with WYDOT for US Highway 89, between Jackson and Hoback Junction. They have raised private funds to monitor wildlife use around and across the highway before the construction of US Highway 89 south of Jackson begins in 2018. There are also other examples of organizations that have a specific focus on implementing collaborative projects for fish passage.

There are many other potential non-profit partners other than environmental/conservation groups in the area that could team with the County on wildlife or aquatic crossing projects, depending on the location, the species of concern, and other aspects of individual mitigation projects. The likelihood that organizations and or individuals would like to engage with the County will become evident once project locations are known and as implementation plans are developed.

10.8. State of Wyoming - Non-transportation Programs

The Wyoming legislature created the Wildlife and Natural Resource Trust (WWNRT) in 2005 and it is used to support any wildlife or natural resource project that improves, restores or maintains wildlife habitat and natural resource values (online at: http://wwnrt.wyo.gov/ [accessed 5 October 2017]). It is considered an independent state agency and is overseen by a board of nine members appointed by the Governor of Wyoming. It has supported over 90 projects across the state, in each county, since its inception. It is possible that a Teton County wildlife crossing may be an appropriate project to receive such funding in the future. The WWNRT leverages its money by a multiple of six, so a future Teton County wildlife crossing partnership that receives contributions from multiple sources may be needed to be successful for these competitive grants.

10.9. Teton County

Teton County's annual budget for Fiscal Year (FY) 2018 was $41.1 million dollars and was comprised of 32 major accounts such as Roads and Bridges $1.7 million (M), Engineering $1.1M and Capital Projects $10M. Within the County's current allocation of funds for its annual budget there are likely limited funds available for funding wildlife crossing projects, particularly if the County bears the full costs of their design and build contracts.

However, discretionary funds from County budgets could be made available for future projects or to support a portion of a multiple-source funding partnership. One such source is the County's Special Purpose Excise Taxes (SPET) funds. In the County's FY 2018 budget SPET funded a Parks and Recreation facility, government employee housing and fire station improvements. In the future, it is possible for SPET funds to be approved by County voters for use in wildlife crossing implementation projects.

An example of an Arizona county that has used a portion of its local sales tax to fund wildlife crossings is Pima County. Citizens of Pima County successfully sought to create a Regional Transportation Authority (RTA) to address regional transportation planning and funding (Campbell and Kennedy 2010). The RTA was approved by voters and funded by a 0.5% sales tax for 20 years. As a result, a portion of the tax revenue, $45M, has been set aside to protect and enhance wildlife connectivity across the county's road system. It allows for funding of design and construction of wildlife crossings for future road projects and retrofitting of existing highways. One such project to tap these funds built an overpass and underpass for wildlife crossings for State Route 77 north of Tucson, AZ (Figure 54). Nationally, this is the first sales tax increase has been approved by citizens to help reduce wildlife-highway conflicts and improve connectivity.

Figure 54. Wildlife underpass on State Route 77, Pima County, Arizona. Photo: Rob Ament.

10.9.1. Summary

Simple reliance on existing transportation program funds to meet the needs of Teton County's wildlife crossings will not be sufficient to address all the locations that require mitigation. Therefore, solutions that create partnerships that draw from a variety of resources will be necessary for implementing successful wildlife crossings described in the Wildlife Crossings Master Plan. Many highway mitigation projects have been successful around the U.S. by creating crossings that allow a variety of government agencies, non-profit organizations and individuals to contribute to their success. Such projects have relied on many different people, organizations and funds to be brought together for the common goals of conserving wildlife, making roads safer for motorists and/or improving fish and other aquatic species' passage.

11.REFERENCES

Aikens, E.O., M.J. Kauffman, J.A. Merkle, S.P.H. Dwinnell, G.L. Fralick & K.L. Monteith. 2017. The greenscape shapes surfing of resource waves in a large migratory herbivore. Ecology letters 20(6): 741-750. ISSN: 1461-023X, 1461-0248; DOI: 10.1111/ele.12772

Allen, T.D.H, M.P. Huijser & D. Willey. 2013. Evaluation of wildlife guards at access roads. Effectiveness of wildlife guards at access roads. Wildlife Society Bulletin 37(2): 402–408.

Baker, C.O. & F.E. Votapka. 1990. Fish passage through culverts. FHWA-FL-09-006. USDA Forest Service – Technology and Development Center. San Dimas, California, USA.

Barnard, R.J., J. Johnson, P. Brooks, K.M. Bates, B. Heiner, J.P. Klavas, D.C. Ponder, P.D. Smith & P.D. Powers. 2013. Water crossings design guidelines. Washington Department of Fish and Wildlife, Olympia, Washington, USA.

Barnard, B.J., S. Yokers, A. Nagygyor & T. Quinn. 2015. An evaluation of the stream simulation culvert design method in Washington State. River Research and Applications 31: 1376-1387.

Baxter, C.V. & F.R. Hauer. 2000. Geomorphology, hyporheic exchange, and selection of spawning habitat by bull trout (*Salvelinus confluentus*). Canadian Journal of Fisheries and Aquatic Sciences 57: 1470-1481.

Baxter, J.S., G.J. Birch & W.R. Olmsted. 2011. Assessment of constructed fish migration barrier using radio telemetry and floy tagging. North American Journal of Fisheries Management 23: 1030-1035.

Becker, S.A. 2008. Habitat selection, condition, and survival of Shiras moose in northwest Wyoming. M.S. Thesis, Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming, USA.

Becker, S., M.J. Kauffman & W. Hubert. 2008. Spatial and temporal characteristics of moose highway crossings in the Buffalo Fork Valley, Wyoming. Report FHWA-WY-08/03F, U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, and University of Wyoming, Laramie, Wyoming, USA.

Beebe, T.J. 2013. Effects of road mortality and mitigation measured on amphibian populations. Conservation Biology 27(4): 657-668.

Bing Huang, Yu Zhang, Jian Lu & Linjun Lu. 2013. A Simulation Study for Minimizing Operating Speed Variation of Multilane Highways by Controlling Access, Procedia - Social and Behavioral Sciences 96: 2767-2781.

Blank, M.D. 2010. Chapter 4: Safe Passages for Fish and Other Aquatic Species. In Safe Passages, edited by J.P. Beckman, A.P. Clevenger, M.P. Huijser & J.A. Hilty. Island Press. Washington DC, USA.

Bouska, W.W. & C.P. Paukert. 2009. Road crossing designs and their impact on fish assemblages of Great Plains streams. Transactions of the American Fisheries Society 139: 214-222.
Burford, D.D., T.E. McMahon, J.E. Cahoon & M. Blank. 2009. Assessment of trout passage through culverts in a large Montana drainage during summer low flow. North American Journal of Fisheries Management 29: 739-752.

Callahan, R. & R. Ament. 2012. Synopsis of wildlife provisions in MAP-21's surface transportation programs, plans and projects. Center for Large Landscape Conservation. Bozeman, Montana, USA. Online at: http://largelandscapes.org/media/publications/Synopsis-of-Wildlife-Provisions-MAP-21.pdf

Campbell, C. & K. Kennedy. 2010. The Sonoran Desert conservation plan and regional transportation authority: Citizen support for habitat connectivity and highway mitigation. *In:* Safe passages, highways, wildlife and habitat connectivity, J.P. Beckmann, A.P. Clevenger, M.P. Huijser and J.A. Hilty, editors, Washington, D.C.: Island Press, 396 pp.

Castrol, J. & A. Beavers. 2016. Providing aquatic organism passage in vertically unstable streams. Water-Open Access Journal 8 (4).

Coe, D. 2004. The hydrologic impacts of roads at varying spatial and temporal scales: A review of published literature as of April 2004. Unpublished report.

Colorado Department of Transportation (CDOT). 2012. Wildlife crossing zones report. Colorado Department of Transportation, to the House and Senate Committees on Transportation, Denver, Colorado, USA.

Clevenger, A.P. & M.P. Huijser. 2011. Wildlife crossing structure handbook design and evaluation in North America. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.westerntransportationinstitute.org/documents/reports/425259_Final_Report.pdf

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

Connolly-Newman, H.R. 2013. Effect of cover on small mammal abundance and movement through wildlife underpasses. Graduate Student Theses, Dissertations, & Professional Papers. 350. http://scholarworks.umt.edu/etd/350

Conover, M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow & W.A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23: 407–414.

Courtemanch, A.B., M.J. Kauffman, S. Kilpatrick & S.R. Dewey. 2017. Alternative foraging strategies enable a mountain ungulate to persist after migration loss. Ecosphere 8(6), p.e01855 ISSN: 21508925, 2150-8925; DOI: 10.1002/ecs2.1855

Cramer, P.C. & R.F. Hamlin. 2017. Evaluation of wildlife crossing structures on US 93 in Montana's Bitterroot Valley. Report FHWA/MT-17-003/8194. Montana Department of Transportation, Helena, Montana, USA.

Cuperus, R., K.J. Canters, H.A. Udo de Haes & D.S. Friedman. 1999. Guidelines for ecological compensation associated with highways. Biological Conservation 90: 41-51.

Dodd, N., J.W. Gagnon, S. Boe & R.E. Schweinsburg. 2007. Role of fencing in promoting wildlife underpass use and highway permeability. In: Proceedings of the 2007 International Conference on Ecology and Transportation, edited by C.L. Irwin, D. Nelson & K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2007. pp 475-487.

Donaldson, B.M. & N.W. Lafon. 2008. Testing an integrated PDA-GPS system to collect standardized animal carcass removal data. FHWA/VTRC 08-CR10. Virginia Transportation Research Council, Charlottesville, Virginia, USA.

Donnell, E., K. Kersavage & L. Fontana Tierney. 2018. Self-Enforcing Roadways: A Guidance Report. PUBLICATION NO. FHWA-HRT-17-098. Institute of Transportation Engineers, Washington, DC, USA.

Ead, S.A., N. Rajaratnam & C. Katopodis. 2002. Generalized study of hydraulics of culvert fishways. Journal of Hydraulic Engineering 128: 1018-1022.

Edwards, R.T. 1998. The hyporheic zone in R.J. Naiman & R.E. Bibly, eds. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer-Verlag, New York, USA.

Elvik, R. 2014. Speed and road safety - new models. TØI report: 1296/2014. Transportøkonomisk institutt, Oslo, Norway.

Evink, G.L. 2002. NCHRP Synthesis 305: interaction between roadways and wildlife ecology: a synthesis of highway practice. Transportation Research Board. National Academies, Washington, DC, USA.

Fitch, M.G. 1995. Nonanadromous fish passage in highway culverts. VTRL 96-R6. Virginia Transportation Research Council. Charlottesville, VA, USA.

Fitzpatrick, K, P. Carlson, M.A. Brewer, M.D. Wooldridge & S.-P. Miaou. 2003. Design Speed, Operating Speed, and Posted Speed Practices. NCHRP Report 504. National Cooperative Highway Research Program, Transportation Research Board of the National Academies.

Ford, A.T., A.P. Clevenger & K. Rettie. 2010. The Banff wildlife crossings project: An international public private partnership. In: J.P. Beckmann, A.P. Clevenger, M.P. Huijser & J.A. Hilty (Eds.). Safe passages- highways, wildlife and habitat connectivity. Island Press, Washington, DC, pp. 157–173.

Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R. France, C.R. Goldman, K. Heanue, J.A. Jones, F.J. Swanson, T. Turrentine & T.C. Winter. 2003. Road ecology: science and solutions. Island Press, Washington DC, USA.

Gagnon, J.W., N.L. Dodd, S.C. Sprague, K. Ogren & R.E. Schweinsburg. 2010. Preacher canyon wildlife fence and crosswalk enhancement project evaluation. State Route 260. Final report – Project JPA 04-088. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Giller, P.S. & B. Malmqvist. 1998. The biology of streams and rivers. Oxford University Press, New York, USA.

Goerig, E., T. Castro-Santos & N.E. Bergeron. 2016. Brook trout passage performance through culverts. Canadian Journal of Fisheries and Aquatic Sciences 73: 94-104.

Gomes L., C. Grilo, C. Silva &A. Mira. 2009. Identification methods and deterministic factors of owl roadkill hotspot locations in Mediterranean landscapes. Ecological Research 24(2): 355-370.

Honeycutt, R.K., W.H. Lower & B.R. Hossack. 2016. Movement and survival of an amphibian in relation to sediment and culvert design. Journal of Wildlife Management 80(4): 761-770.

Hood, P., A. Courtemanch & J. Mobeck. 2017. Jackson Hole Wildlife Foundation's Teton County wildlife-vehicle collision database summary report 2016/2017. Published October 2017 covering May 2016 - April 2017. Jackson Hole Wildlife Foundation - Nature Mapping Jackson Hole program, Jackson, Wyoming, USA.

Huijser, M.P. & P.J.M. Bergers. 2000. The effect of roads and traffic on hedgehog (*Erinaceus europaeus*) populations. Biological Conservation 95: 111–116.

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

Huijser, M.P., J. Fuller, M.E. Wagner, A. Hardy, & A.P. Clevenger. 2007a. Animal-vehicle collision data collection. A synthesis of highway practice. NCHRP Synthesis 370. Project 20-05/Topic 37-12. Transportation Research Board of the National Academies, Washington DC, USA. Available from the internet: http://www.trb.org/news/blurb_detail.asp?id=8422

Huijser, M.P., A. Kociolek, P. McGowen, A. Hardy, A.P. Clevenger & R. Ament. 2007b. Wildlife-vehicle collision and crossing mitigation measures and associated costs and benefits: A toolbox for the Montana Department of Transportation. FHWA/MT-07-002/8117-34. Western Transportation Institute – Montana State University, Bozeman, MT, USA.

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

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

Huijser, M.P., R.J. Ament & J.S. Begley. 2011. Highway mitigation opportunities for wildlife in Jackson Hole, Wyoming. Report 4W3520 Western Transportation Institute – Montana State University, Bozeman, MT, USA.

.

Huijser, M.P., C. Mosler-Berger, M. Olsson & M. Strein. 2015a. Wildlife warning signs and animal detection systems aimed at reducing wildlife-vehicle collisions. pp. 198-212. In: R. Van der Ree, C. Grilo & D. Smith. Ecology of roads: A practitioner's guide to impacts and mitigation. John Wiley & Sons Ltd. Chichester, United Kingdom.

Huijser, M.P., A.V. Kociolek, T.D.H. Allen, P. McGowen, P.C. Cramer & M. Venner. 2015b. Construction guidelines for wildlife fencing and associated escape and lateral access control measures. NCHRP Project 25-25, Task 84, National Cooperative Highway Research Program, Transportation Research Board of the National Academies, Washington D.C., USA.

Huijser, M.P. & J.S. Begley. 2015. An analysis of wildlife-vehicle collisions, wildlife connectivity concerns and potential mitigation measures, US Hwy 89, National Elk Refuge, Wyoming, USA. Report No. 4W4838-09. Western Transportation Institute – Montana State University, Bozeman, Montana, USA.

Huijser, M.P., E.R. Fairbank, W. Camel-Means, J. Graham, V. Watson, P. Basting & D. Becker. 2016a. Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife-vehicle collisions and providing safe crossing opportunities for large mammals. Biological Conservation 197: 61-68.

Huijser, M.P., W. Camel-Means, E.R. Fairbank, J.P. Purdum, T.D.H. Allen, A.R. Hardy, J. Graham, J.S. Begley, P. Basting & D. Becker. 2016b. US 93 North post-construction wildlife-vehicle collision and wildlife crossing monitoring on the Flathead Indian Reservation between Evaro and Polson, Montana. FHWA/MT-16-009/8208. Western Transportation Institute – Montana State University, Bozeman, Montana, USA

Huijser, M.P., B. Sloan, E.R. Fairbank & F.D. Abra. 2017. The reliability and effectiveness of a radar based animal detection system and road crossing behavior of large ungulates along US

Hwy 95, Idaho, USA. FHWA-ID-17-247. Western Transportation Institute College of Engineering, Montana State University, P.O. Box 174250. Bozeman, MT 59717-4250, USA.

Iuell, B., Bekker, G.J. (Hans)., Cuperus, R., Dufek, J., Fry, G., Hicks, C., Hlavác, V. Keller, V., Le Maire Wandall, B., Rosell, C., Sangwine, T., Törsløv, N. 2003. Wildlife and traffic: a European handbook for identifying conflicts and designing solutions. Prepared by COST 341 - Habitat fragmentation due to transportation infrastructure.

Jacobs. 2014. Wyoming highways 22 and 390. Planning and environmental linkages study. Jacobs.

Jaeger, J.A.G. & L. Fahrig. 2004. Effects of road fencing on population persistence. Conservation Biology 18(6): 1651-1657.

Jiang, Z. K. Jadaan & Y. Ouyang. 2016. Speed Harmonization—Design Speed vs. Operating Speed. FHWA-ICT-16-019. Illinois Center for Transportation, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, 205 North Mathews Avenue, MC-250, Urbana, Illinois, USA.

Jones, J.A., F.J. Swanson, B.C. Wemple & K.U. Snyder. 2000. Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks. Conservation Biology 14: 76-85.

Knapp, K.K., X. Yi, T. Oakasa, W. Thimm, E. Hudson & C. Rathmann. 2004. Deer vehicle crash countermeasure tool box: A decision and choice resource. Final report. DVCIC-02. Midwest Regional University Transportation Center, Deer Vehicle Crash Information Clearinghouse, University of Wisconsin-Madison, Madison, WI.

Lachance, S., M. Dube, R. Dostie & P. Berube. 2008. Temporal and spatial quantification of fine-sediment accumulation downstream of culverts in brook trout habitat. Transactions of the American Fisheries Society 137(6): 1826-1838.

Lavis, D.S., A. Hallett, E.M. Koon & T.C. Mcauley. 2003. History of and advance in barriers as an alternative method to suppress sea lampreys in the Great Lakes. Journal of Great Lakes Research 29(1): 362-372.

Lawler, J.J., T.H. Tear, C. Pyke, M.R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, L., Hannah, K. Klausmeyer, A. Aldous, C. Bienze & S. Pearsall. 2009. Resource management in a changing and uncertain climate. Frontiers in ecology and the environment; 7, doi:10.1890/070146.

MacDonald, J.I. & P.E. Davies. 2007. Improving the upstream passage of two galaxiid fish species through a pipe culvert. Fisheries Management and Ecology 14(3): 221-230.

Maine Department of Transportation. 2008. Waterway and wildlife crossing policy and design guide for aquatic organisms. Wildlife habitat, and hydrologic connectivity. 3rd Edition, Transportation Documents. Paper 8. http://digitalmaine.com/mdot_docs/8

Maitland, B.M., M. Poesch & A.E. Anderson. 2016. Industrial road crossings drive changes in community structure and instream habitat for freshwater fished in the boreal forest. Freshwater biology 61(1): 1-18.

McKay, S.K., J.R. Schramski, J.N. Conyngham & J.C. Fischenich. 2013. Assessing upstream fish passage connectivity with network analysis. Ecological Applications 23(6): 1396-1409.

Morita, K. & S. Yamamoto. 2002. Effects of habitat fragmentation by damming on the persistence of stream-dwelling charr populations. Conservation Biology 16: 1318-1323.

Morris, B.C., M.C. Bolding, W.M. Aust, K.J. McGuire, E.B. Schilling & J. Sullivan. 2016. Differing levels of forestry best management practices at stream crossing structures affect sediment delivery and installation Costs. Water 8, 92.

Myers, R.L. & S. Nieraeth. 2016. Restoration and coho salmon carrying capacity of Chester Creek, an urban stream in Anchorage, Alaska. Northwest Science 90(2): 146-158.

National Park Service. 2017. Climate Change. Yellowstone. National Park Service, U.S. Department of Interior. https://www.nps.gov/yell/learn/nature/climatechange.htm. Unknown Published Date. Web. April 2017.

Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation. 2017a. Wildlife-Vehicle Collision Database, Jackson Hole Wildlife Foundation, Jackson, Wyoming, USA

Nature Mapping Jackson Hole / Jackson Hole Wildlife Foundation. 2017b. Observational Wildlife Data, Jackson Hole Wildlife Foundation, Jackson, Wyoming, USA

North Carolina Department of Transportation. 2003. Best management practices for construction and maintenance activities. August 2003. Website accessed.

Olsson Associates. 2016. Final Upper Snake River Level I Watershed Study. November 1, 2016.

Ottburg, F.G.W.A. & Th. de Jong. 2006 [in Dutch]. Fishes in polder ditches; the influence of dredging in 'isolated' and open ditches on fresh water fish and amphibians. Alterra-report 1349. Alterra, Wageningen, The Netherlands.

Paige, C. 2012. A landowner's guide to wildlife friendly fences. Second edition. Private land technical assistance Program, Montana Fish, Wildlife & Parks, Helena, Montana, USA. 56 pp.

Paul, K.S., M.S. Quinn & M.P. Huijser, J. Graham & L. Broberg. 2014. An evaluation of citizen science data for monitoring wildlife along a highway right-of-way. Journal of Environmental Management 139: 180-187.

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

Purdum, J.P. 2013. Acceptance of wildlife crossing structures on US Highway 93 Missoula, Montana. Theses, Dissertations, Professional Papers. Paper 47. University of Montana, Missoula, Montana, USA.

Riginos, C., K. Krasnow, E. Hall, M. Graham, S. Sundaresan, D. Brimeyer, G. Fralick & D. Wachob. 2013. Mule deer (*Odocoileus hemionus*) movement and habitat use patterns in relation to roadways in northwest Wyoming. Final Report FHWA WY - 13/08F. Wyoming Department of Transportation, Cheyenne, Wyoming, USA.

Riginos, C., M.W. Graham, M. Davis, C. Smith & A. Johnson. 2015. Effects of wildlife warning reflectors (“deer delineators”) on wildlife-vehicle collisions in central Wyoming. Report FHWA-WY-15/03F. Wyoming Department of Transportation, Cheyenne, Wyoming, USA.

Riginos, C., H. Copeland, C. Smith, H. Sawyer, K. Krasnow & T. Hart. 2016. Planning-support for mitigation of wildlife-vehicle collisions and highway impacts on migration routes in Wyoming. Report No. FHWA-WY-16/10F. Teton Science Schools, Jackson, Wyoming, USA.

Riginos, C. 2017. Maps. Deer, elk and moose collisions per mile 2011-2015. http://www.corinnariginos.com/Maps.php

Riley, S.J. & A. Marcoux. 2006. Deer–vehicle collisions: an understanding of accident characteristics and drivers’ attitudes, awareness and involvement. Research report RC-1475. Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan, USA.

Rytwinski, T., R. van der Ree, G.M. Cunnington, L. Fahrig, C.S. Findlay, J. Houlahan, J.A.G. Jaeger, K. Soanes & E.A. van der Grift. 2015. Experimental study designs to improve the evaluation of road mitigation measures for wildlife. Journal of Environmental Management 154: 48-64.

Rytwinski, T., K. Soanes, J.A.G. Jaeger, L. Fahrig, C.S. Findlay, J. Houlahan J, R. van der Ree & E.A. van der Grift. 2016. How effective is road mitigation at reducing road-kill? A meta-analysis. PLoS ONE 11(11): e0166941. https://doi.org/10.1371/journal.pone.0166941

Saldi-Caromile, K., K. Bates, P. Skidmore, J. Barenti & D. Pineo. 2004. Stream habitat restoration guidelines. Co-published by the Washington Departments of Fish and Wildlife and Ecology and the U.S. Fish and Wildlife Service. Olympia, Washington, USA.

Sawaya, M.A., A.P. Clevenger & S.T. Kalinowski. 2013. Demographic connectivity for Ursid populations at wildlife crossing structures in Banff National Park. Conservation Biology 27(4): 721–730.

Sawyer, H., C. LeBeau & T. Hart. 2012. Mitigating roadway impacts to migratory mule deer - A case study with underpasses and continuous fencing. Wildlife Society Bulletin 36(3): 492–498

Sawyer, H., P.A. Rodgers, T. Hart. 2016. Pronghorn and mule deer use of underpasses and overpasses along US Highway 191. Wildlife Society Bulletin 40 (2): 211-216.

Seidler, R.G., R.A. Long, J. Berger, S. Bergen & J.P. Beckmann. 2015. Identifying impediments to long-distance mammal migrations. Conservation Biology 29: 99-109.

Smith, D.J., R. van der Ree & C. Rosell. 2015. Wildlife crossing structures: An effective strategy to restore or maintain wildlife connectivity across roads. pp. 172-183. In: R. Van der Ree, C. Grilo & D. Smith. Ecology of roads: A practitioner's guide to impacts and mitigation. John Wiley & Sons Ltd. Chichester, United Kingdom.

Sullivan, T.L., A.F. Williams, T.A. Messmer, L.A. Hellinga & S.Y. Kyrychenko. 2004. Effectiveness of temporary warning signs in reducing deer-vehicle collisions during mule deer migrations. Wildlife Society Bulletin 32: 907–915.

Tardif, L.-P. & Associates Inc. 2003. Collisions involving motor vehicles and large animals in Canada. Final report. L-P Tardif and Associates Inc., Nepean, Ontario, Canada.

Teton County. 2012. Jackson/Teton County Comprehensive Plan. http://www.tetonwyo.org/compp/topics/jacksonteton-county-comprehensive-plan/251817/

Trombulak, S.C. & C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14: 18-30.

United States Department of Agriculture (USDA). 2008. Stream simulation: An ecological approach to providing passage for aquatic organisms at road-stream crossings. USDA, National Technology Development Program, San Dimas, California, USA.

U.S. Department of Transportation. 2015. International practices on climate adaptation in transportation. Sustainability. U.S. Department of Transportation, Federal Highway Administration. https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/international_practices/page05.cfm. October 28, 2015. Web. April 2017.

US Fish & Wildlife Service. 2017. Wyoming endangered species. Species of concern. https://www.fws.gov/wyominges/species_concern.php

van der Grift, E.A., R. van der Ree, L. Fahrig, S. Findlay, J. Houlahan, J.A.G. Jaeger, N. Klar, L.F. Madrin & L. Olson. 2013. Evaluating the effectiveness of road mitigation measures. Biodiversity and Conservation 22: 425-448.

Van der Ree, R. & E.A. van der Grift. 2015. Recreational co-use of wildlife crossing structures. Pp. 184-189. In: R. Van der Ree, C. Grilo & D. Smith. Ecology of roads: A practitioner's guide to impacts and mitigation. John Wiley & Sons Ltd. Chichester, United Kingdom.

Votapka, F.E. 1991. Considerations for fish passage through culverts. Transportation Research Record 1291: 347-353.

Warren, M.L. & M.G. Pardew. 1998. Road crossings as barriers to small-stream fish movement. Transactions of the American Fisheries Society 127: 637-644.

Wemple, B.C. & J.A. Jones. 2003. Runoff production on forest roads in a steep, mountain catchment. Water Resources Research 39: 1-17.

Winston, M.R., C.M. Taylor & J. Pigg. 1991. Upstream extirpation of four minnow species due to damning of a prairie stream. Transactions of the American Fisheries Society 120: 98-105.

WYDOT. 2016. WYO 390 RM 0.00 to RM 7.00 crash study. (January 1, 2009 to December 31, 2015). Before/interim/after conditions. Update March 2016. Wyoming Department of Transportation. Wyoming, USA.

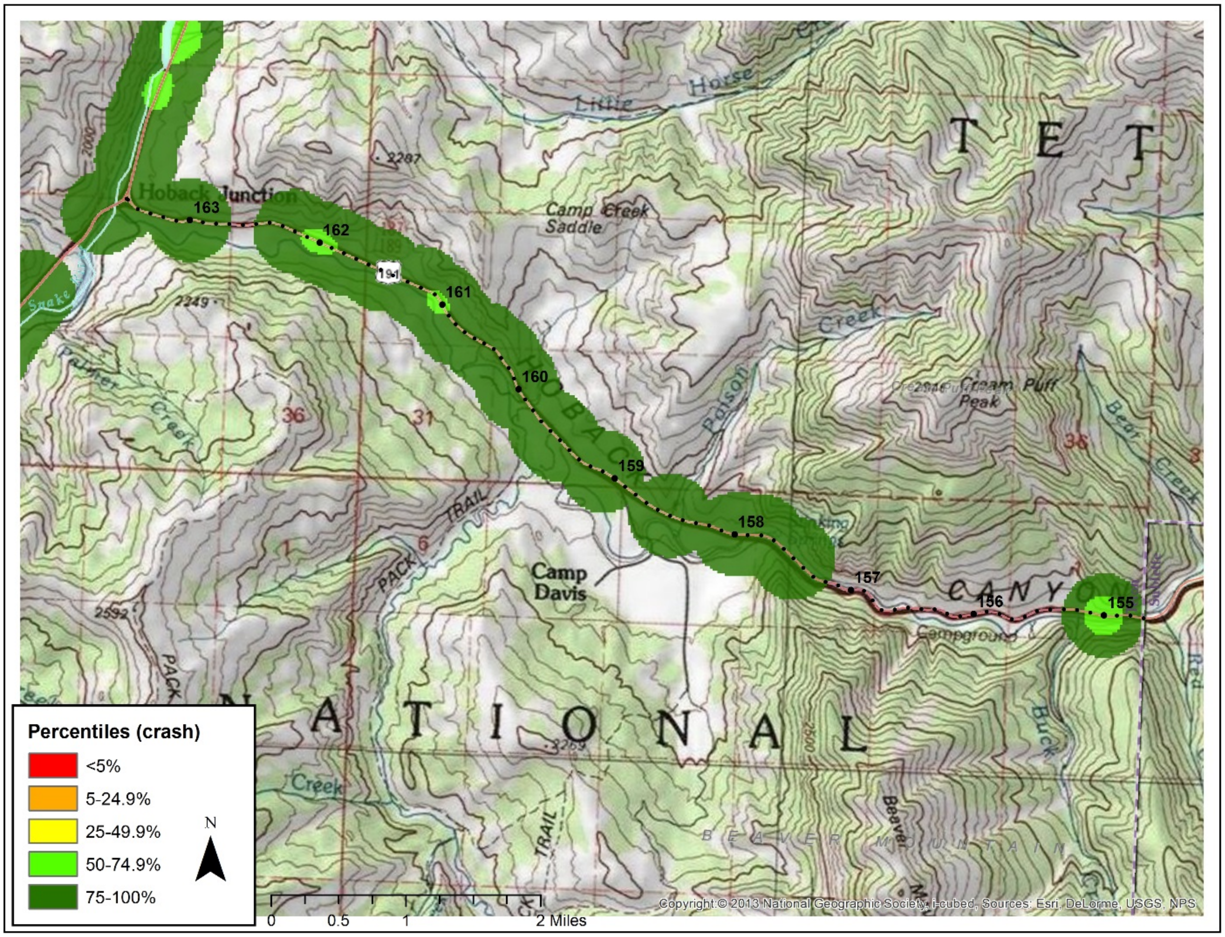
WYDOT. 2017. 2016 Automatic traffic recorder report. Wyoming Department of Transportation, Wyoming, USA.

Wyoming Game & Fish Department. 2017. Species of greatest conservation need. Wyoming Game & Fish Department,Wyoming. https://wgfd.wyo.gov/Habitat/Habitat-Plans/Wyoming-State-Wildlife-Action-Plan/Mammals

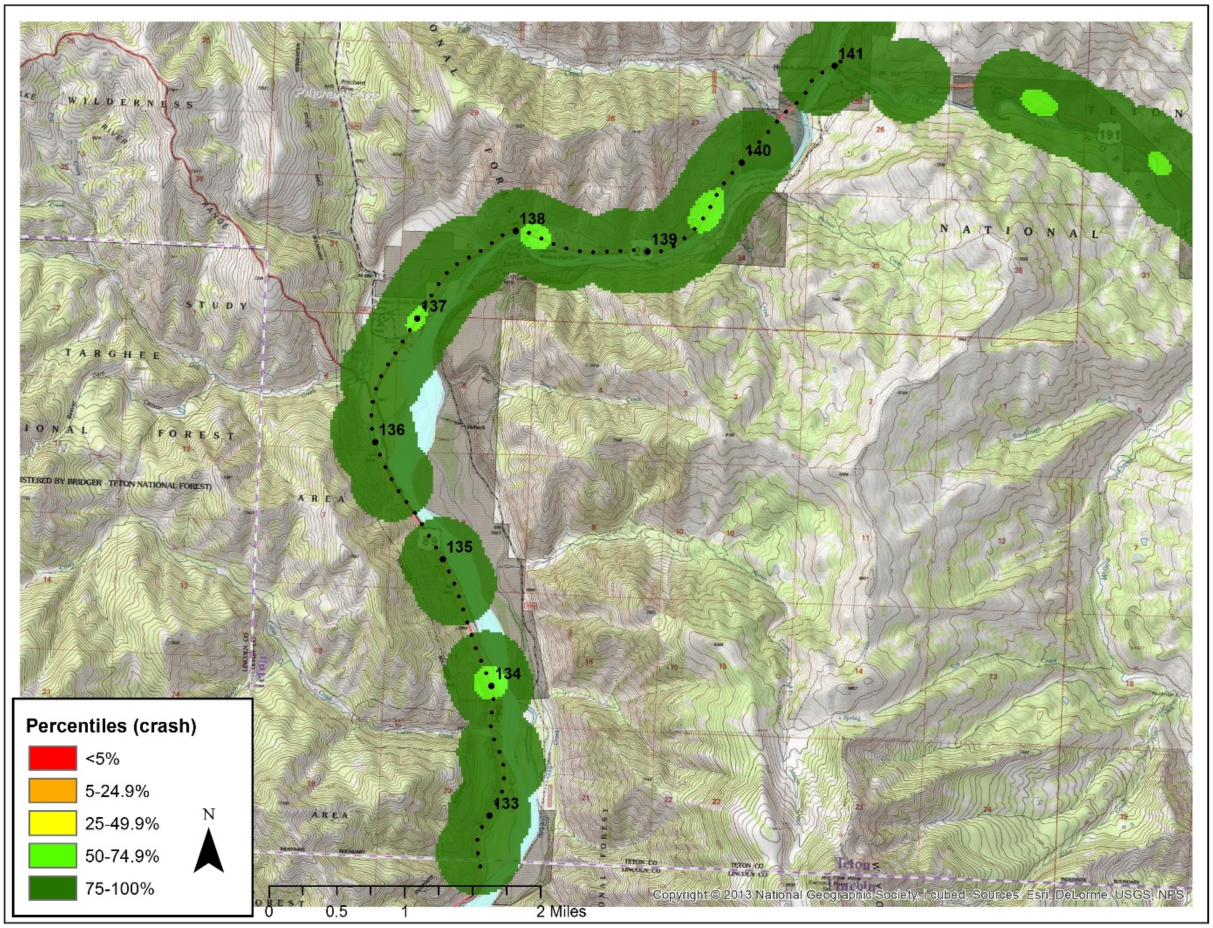
Wyoming Migration Initiative. 2017. Available from the internet: www.migrationinitiative.org

12. APPENDIX A: WILDLIFE-VEHICLE CRASH HOTSPOTS LAW ENFORCEMENT

1. US Hwy 189/191

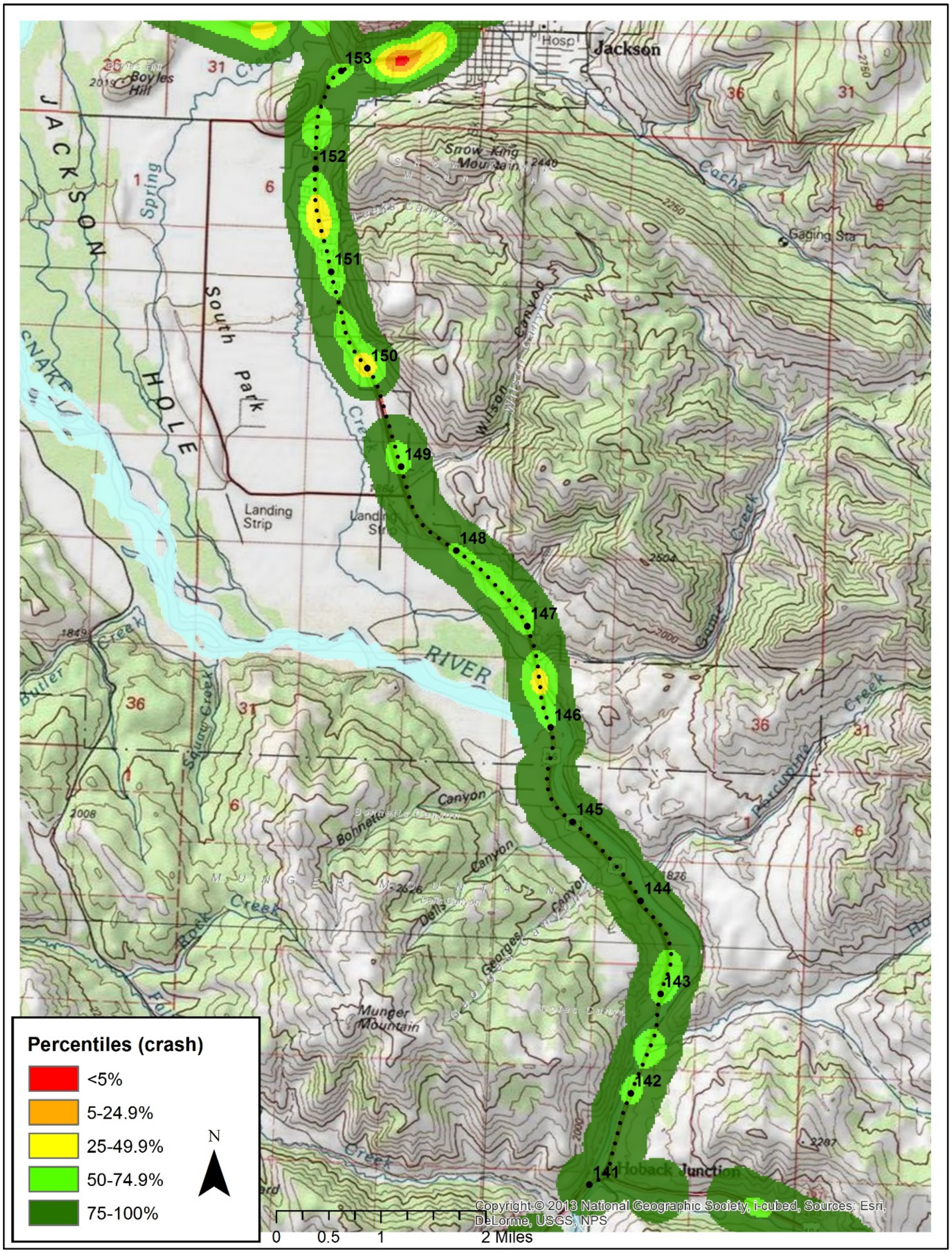


2. US Hwy 89/26

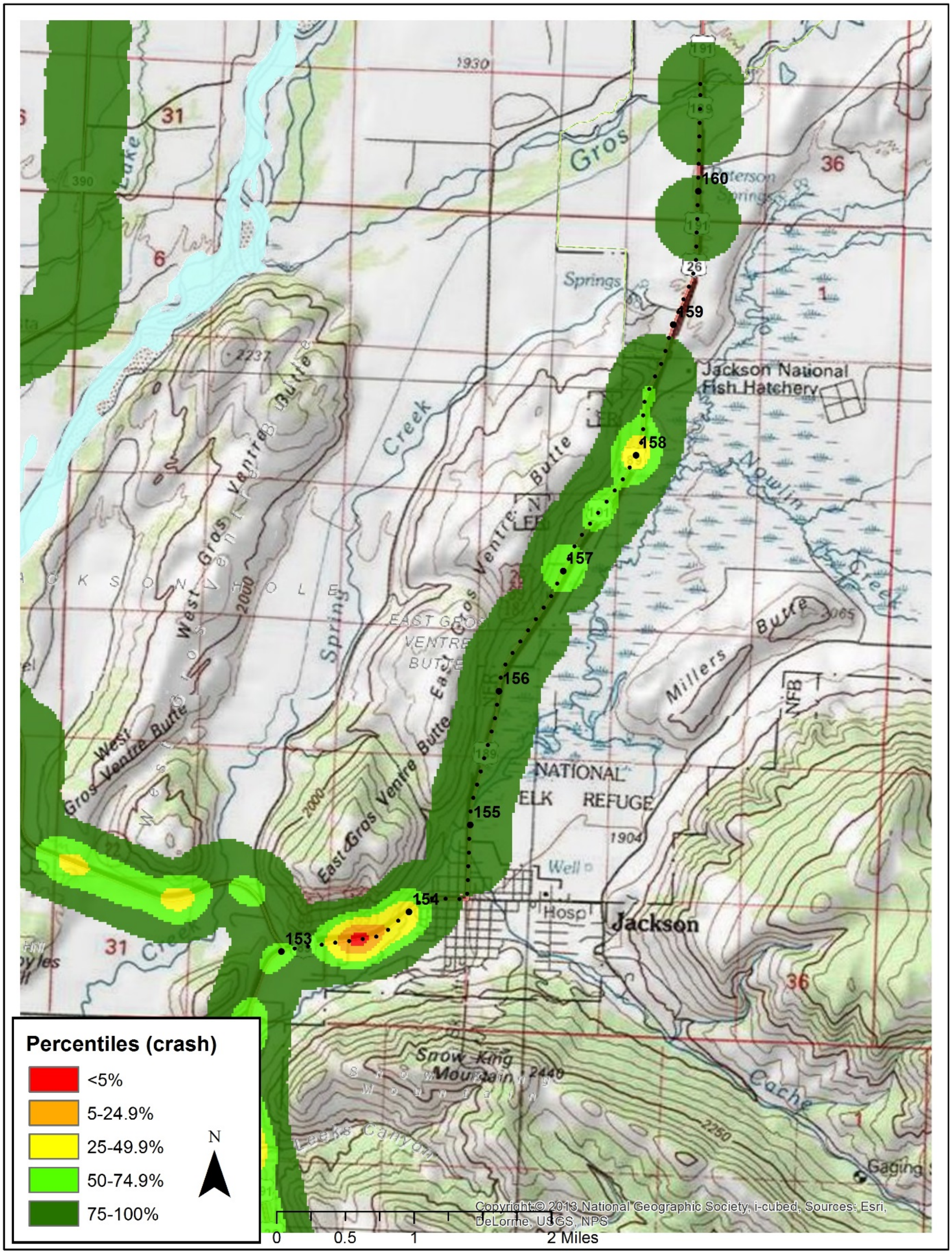


Percentiles (crash)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
133
134
135
136
137
138
139
140
141
Copyright © 2013 National Geographic Society, i-cubed Sources: Esri, DeLorme, USGS, NPS

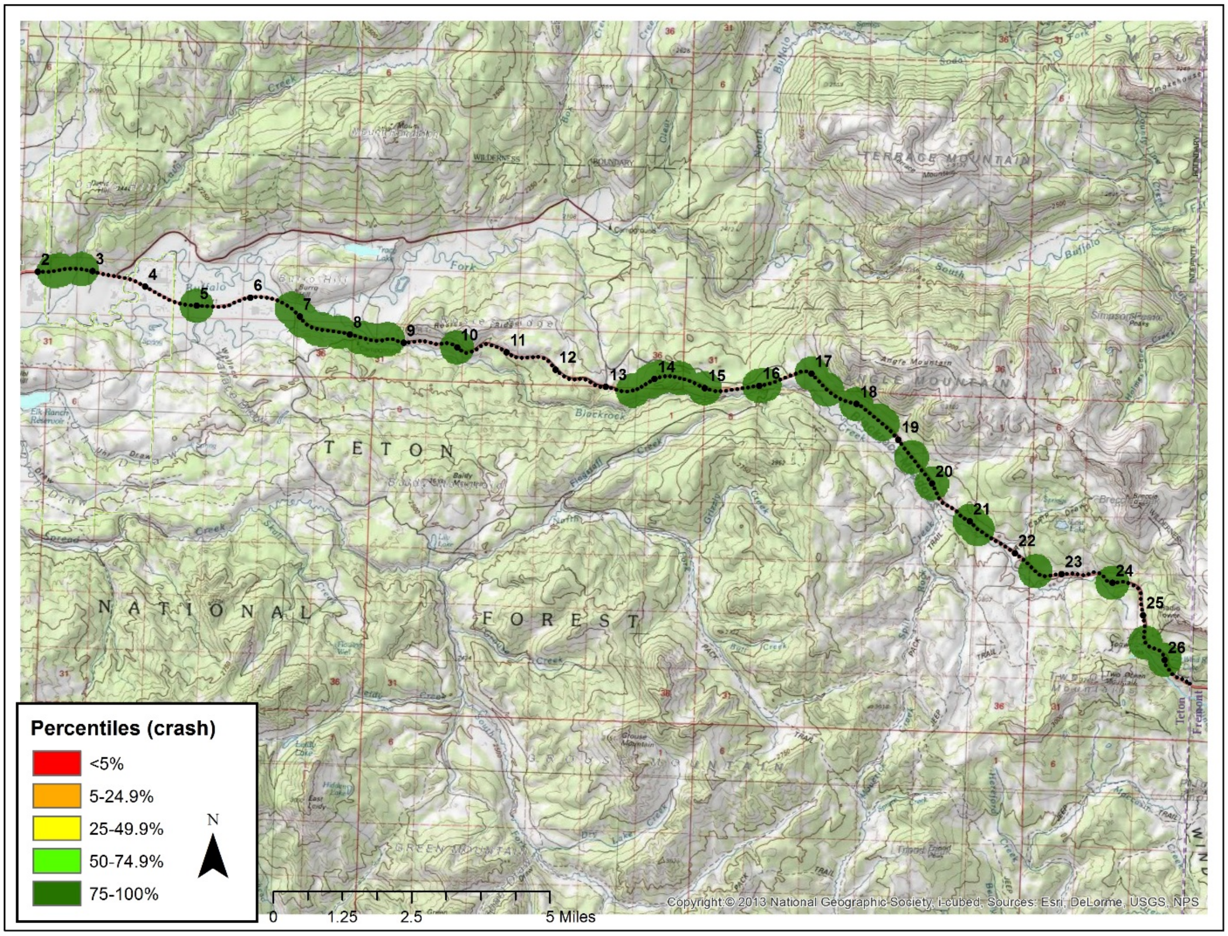
3. US Hwy 26/89/191



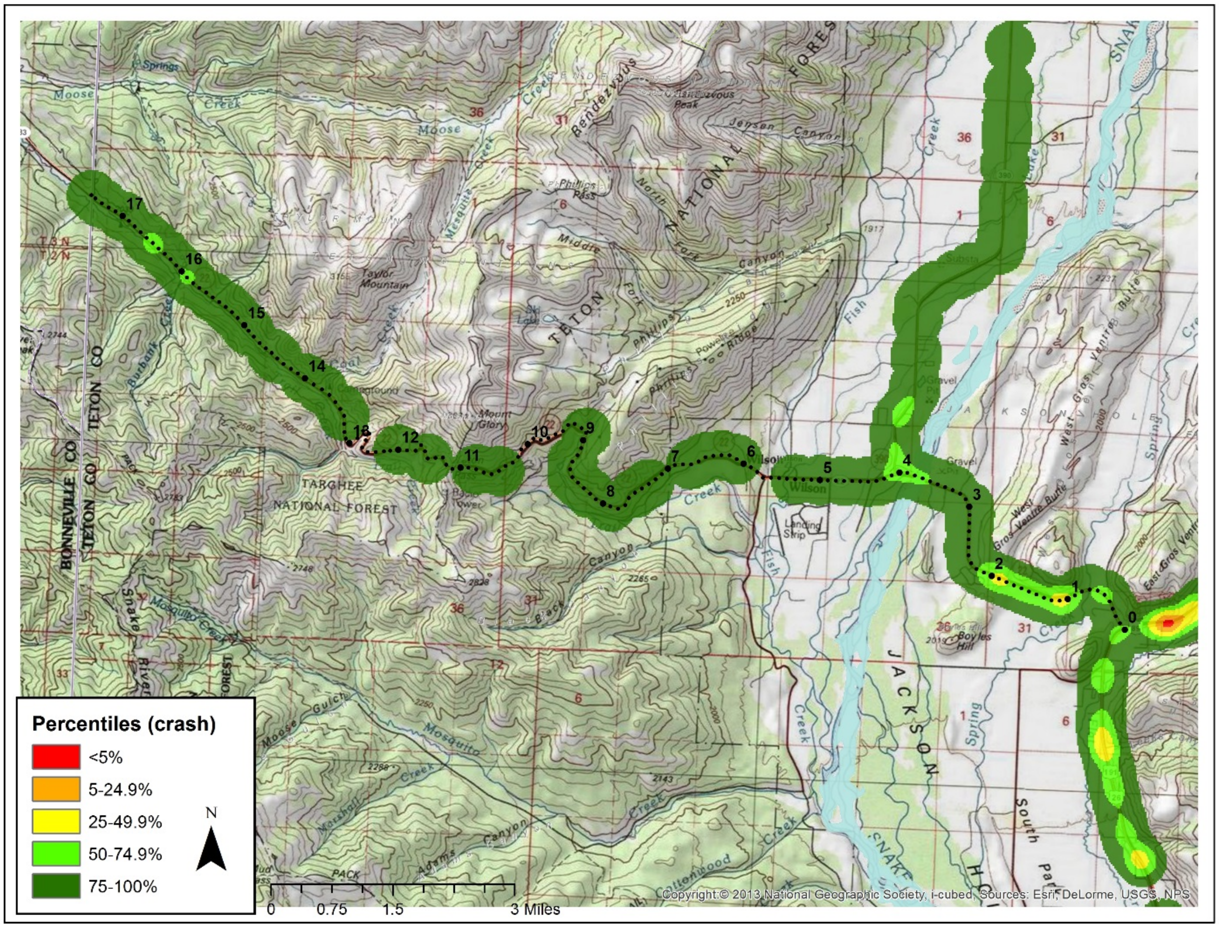
4. US Hwy 26/89/191



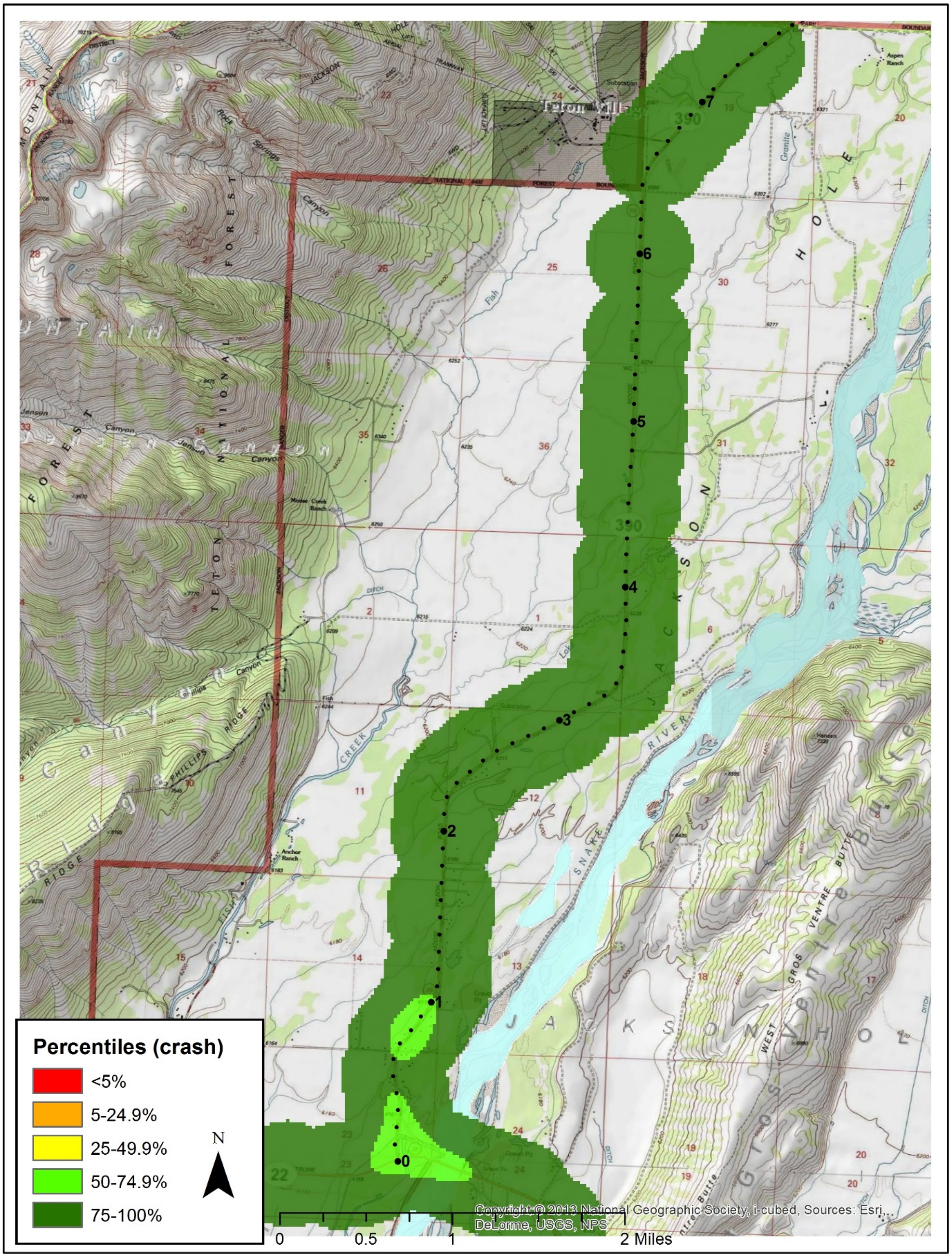
5. US Hwy 26/287



6. WY 22

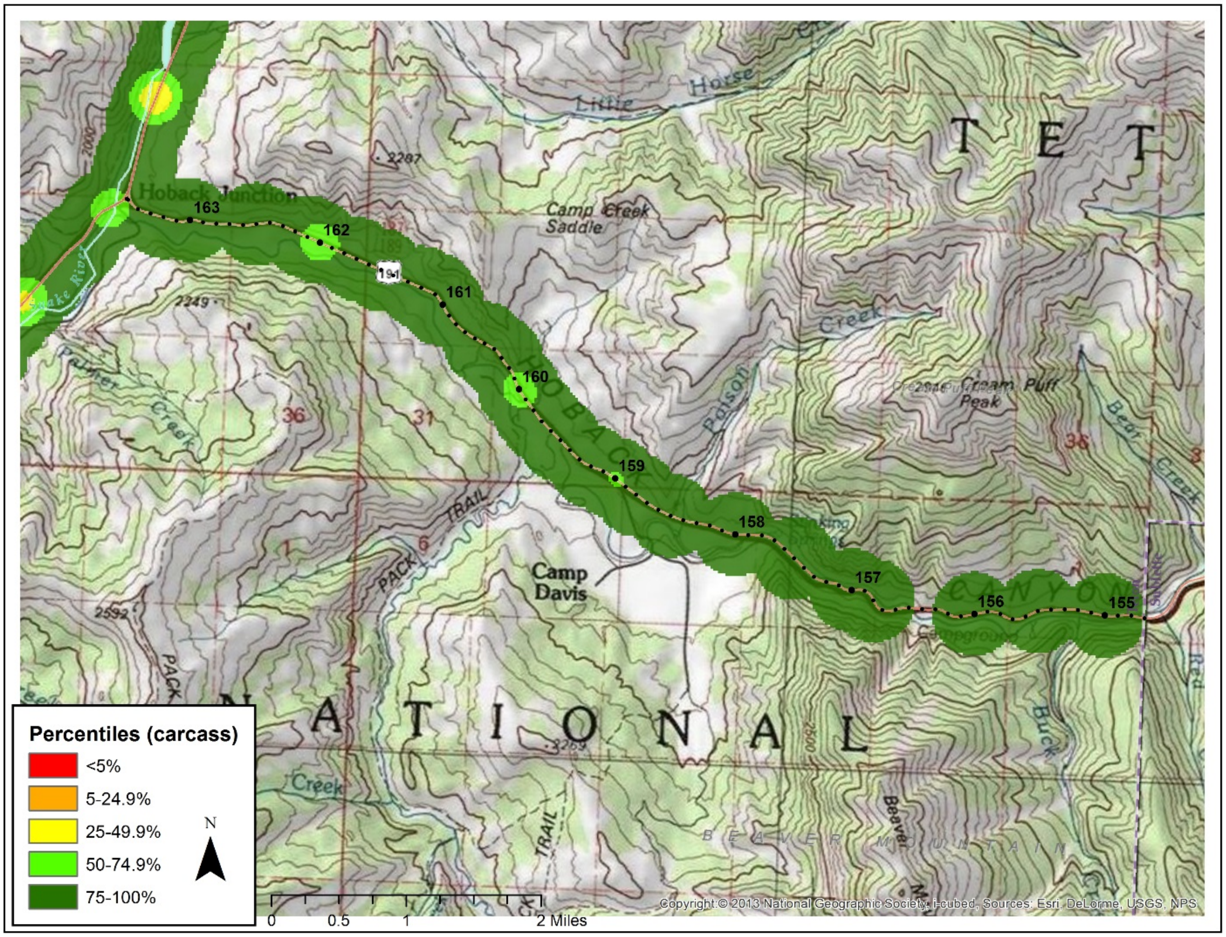

Percentiles (crash)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0 0.75 1.5 3 Miles
Copyright © 2013 National Geographic Society, i-cubed Sources: Esri, DeLorme, USGS, NPS

7. WY 390

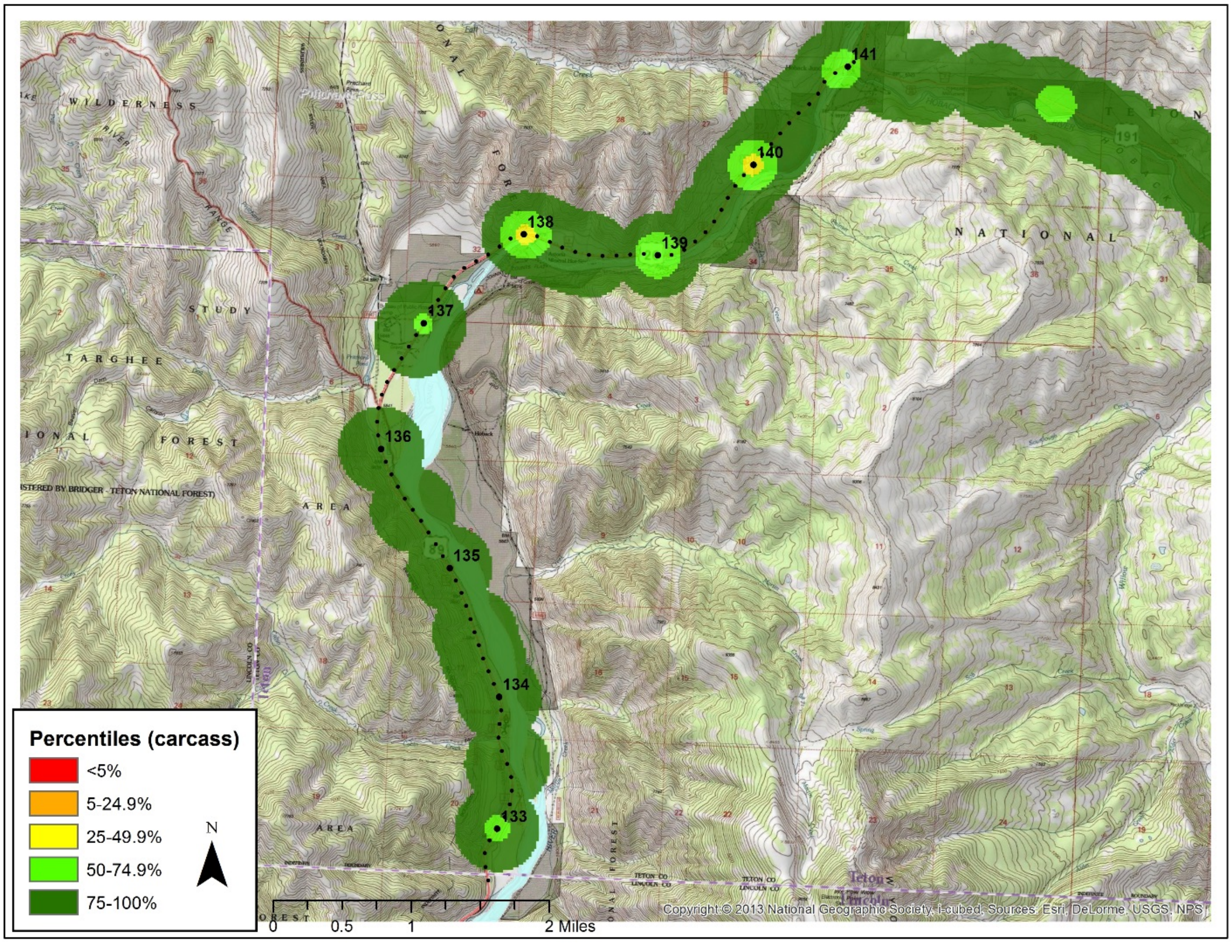

Percentiles (crash)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
Copyright: © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

13.APPENDIX B: CARCASS REMOVAL HOTSPOTS WYDOT

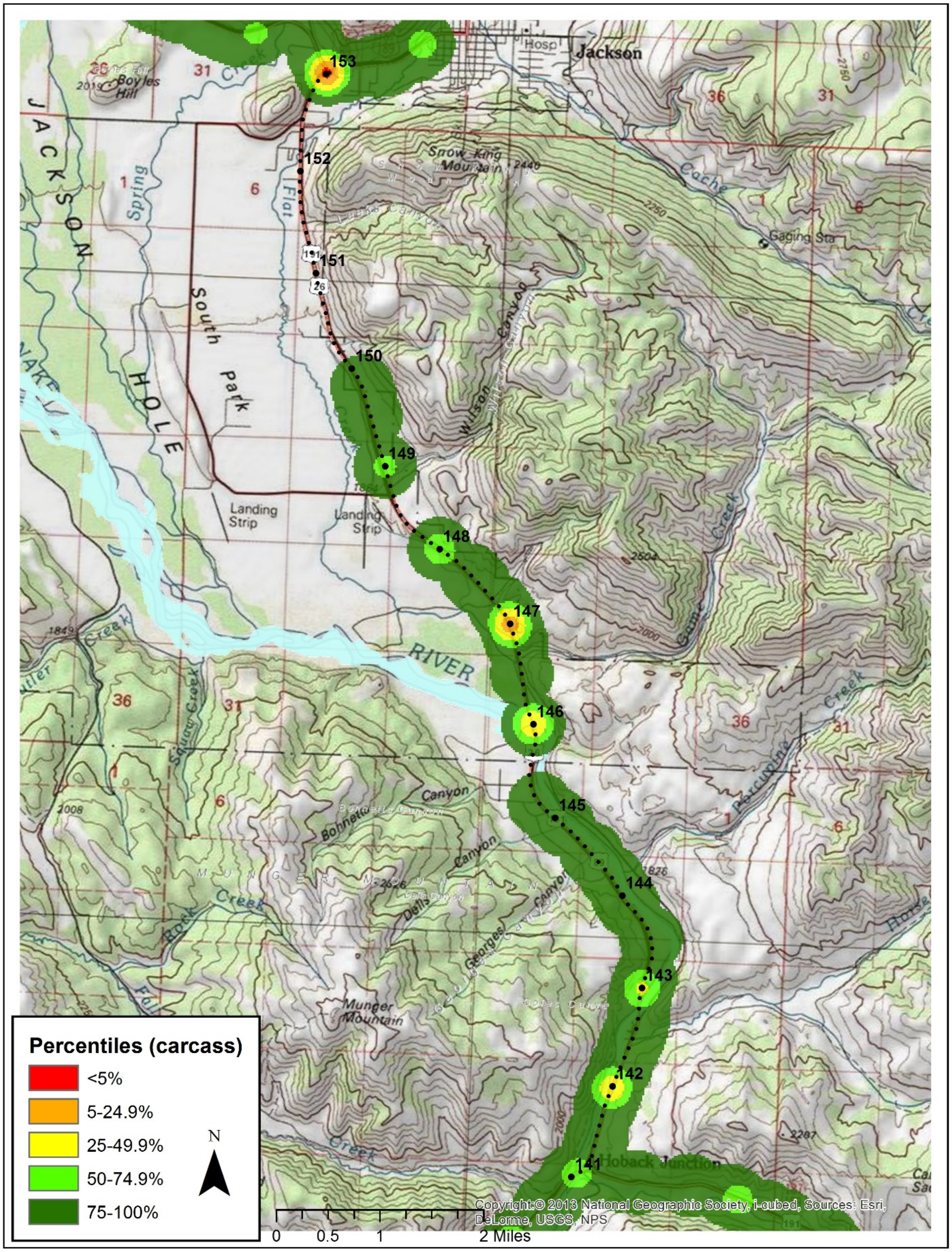
1. US Hwy 189/191



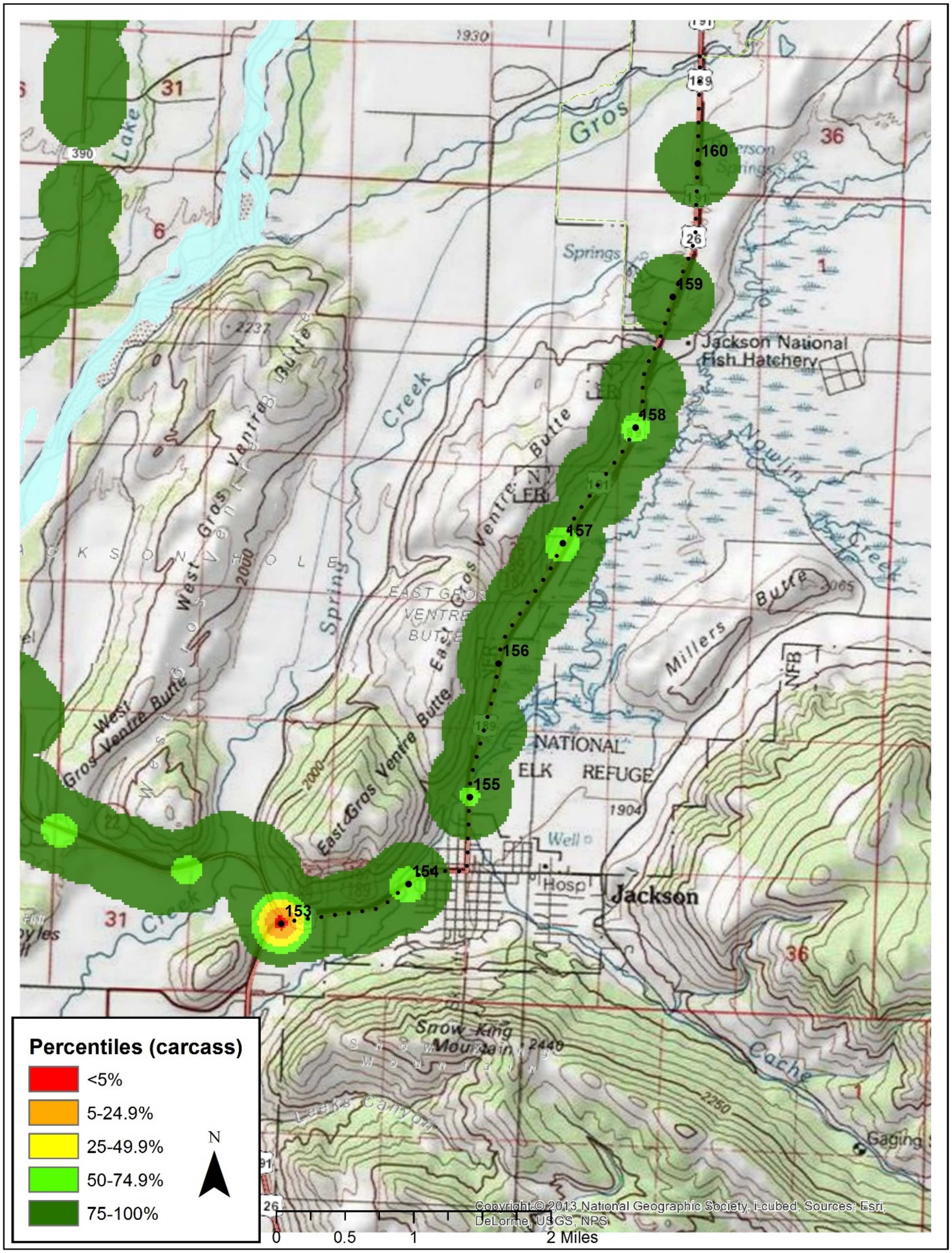
2. US Hwy 89/26


Percentiles (carcass)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
133
134
135
136
137
138
139
140
141
Copyright © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

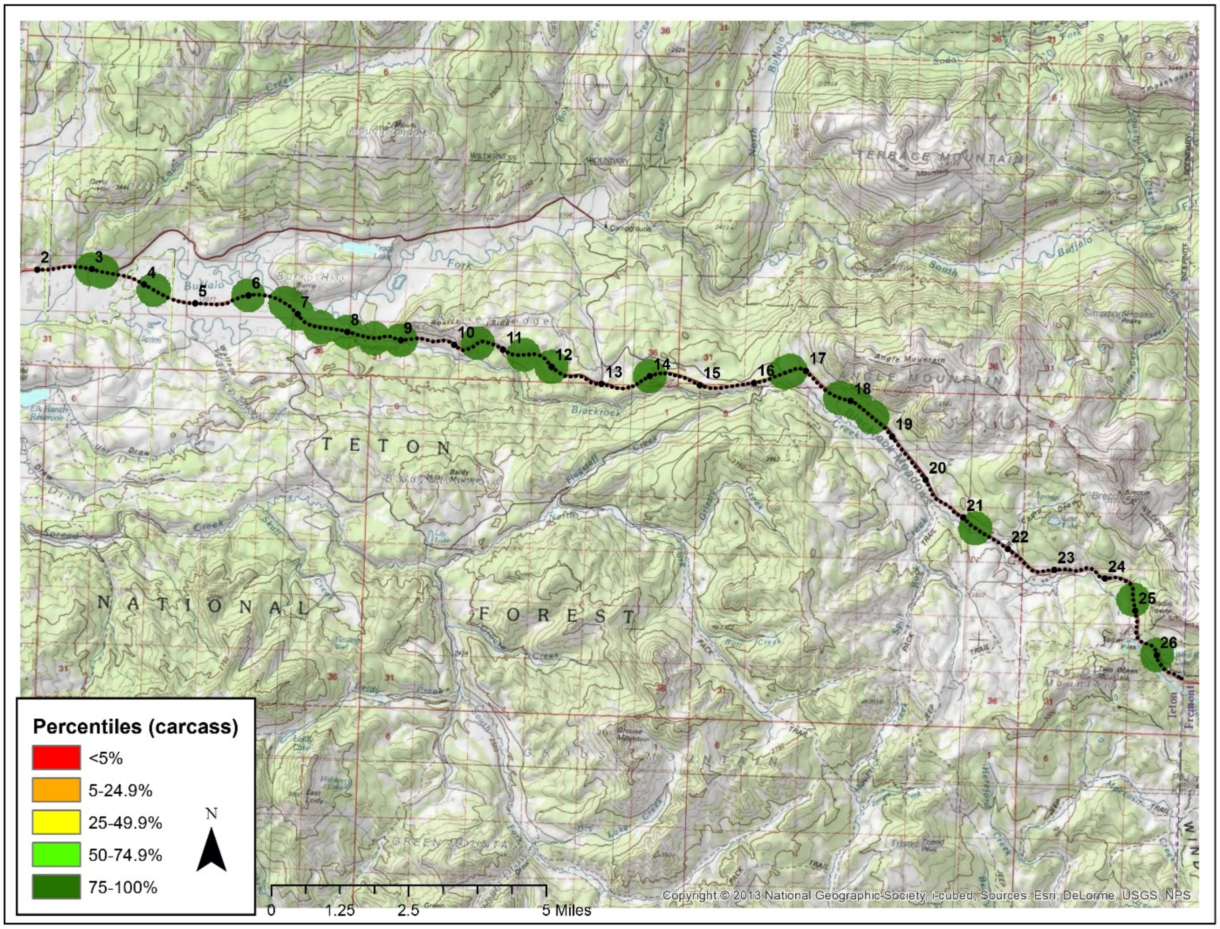
3. US Hwy 26/89/191



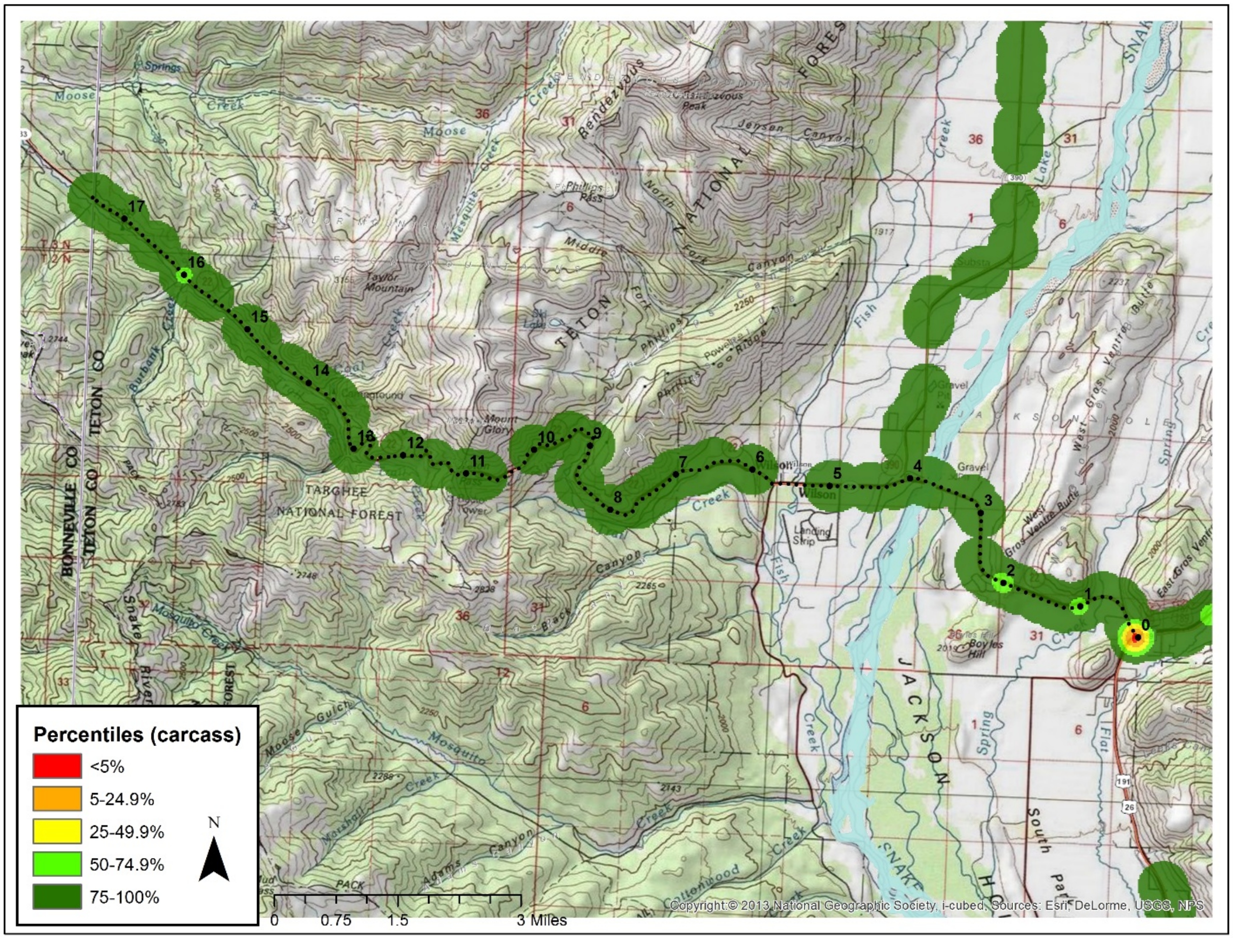
4. US Hwy 26/89/191



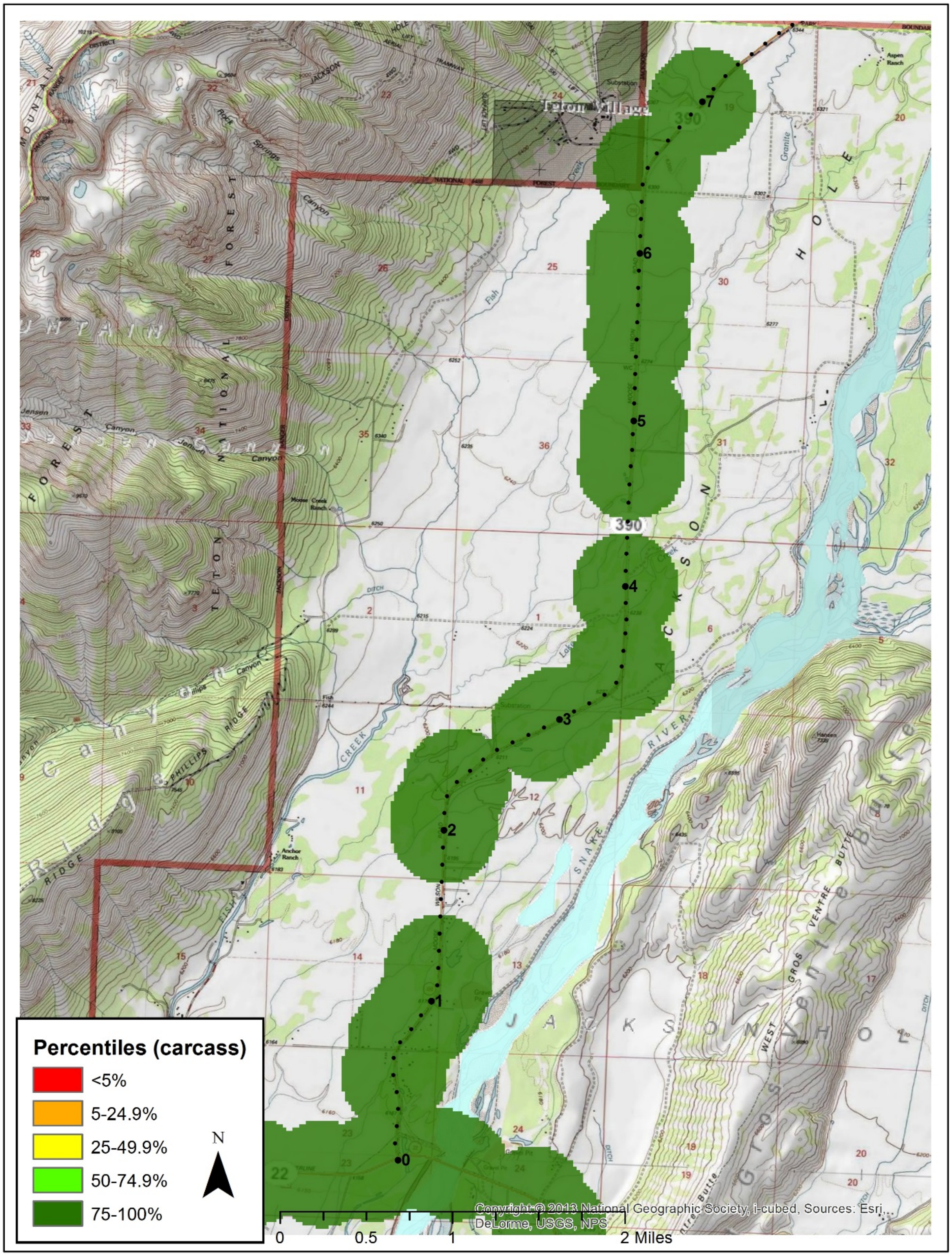
5. US Hwy 26/287



6. WY 22


Percentiles (carcass)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.75
1.5
3 Miles
Copyright: © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

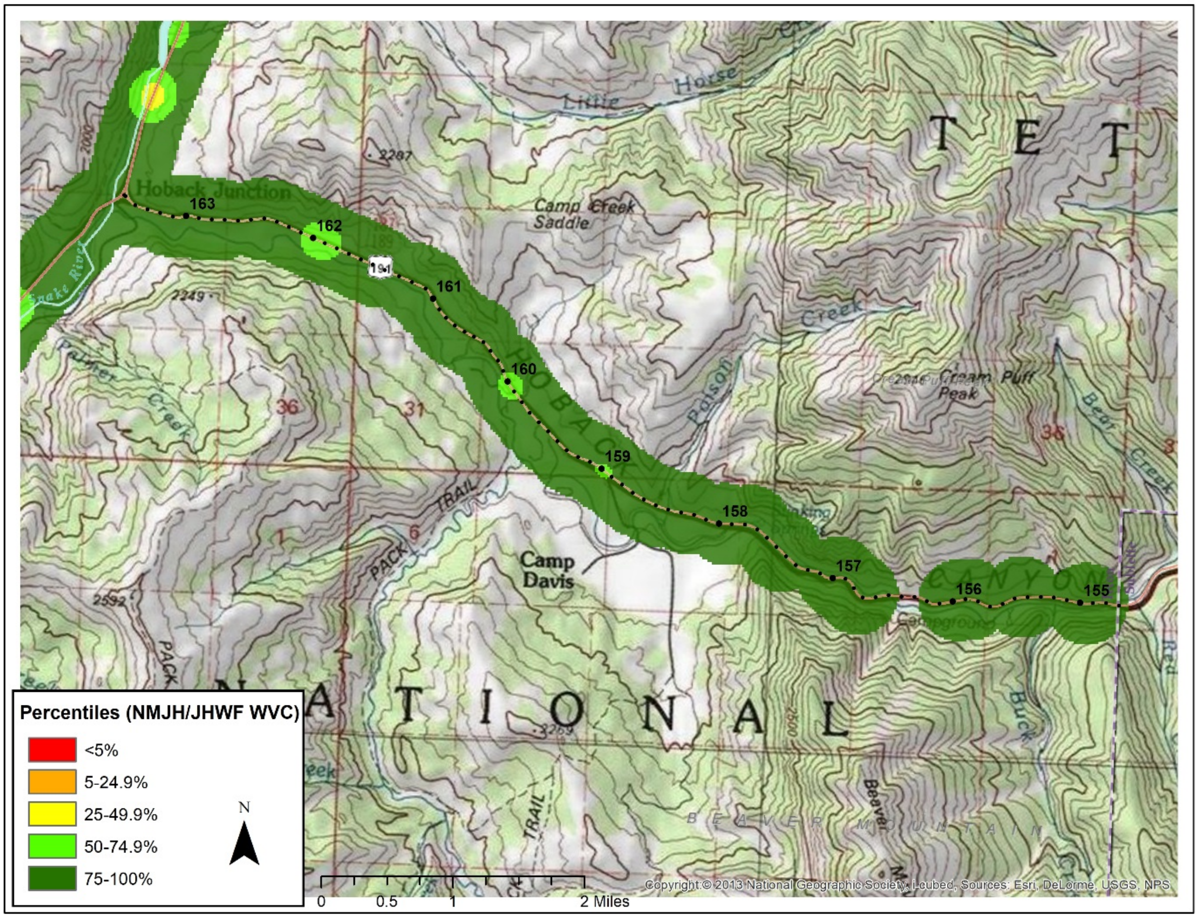
7. WY 390


Percentiles (carcass)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
Copyright:© 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS
390
Teton Village

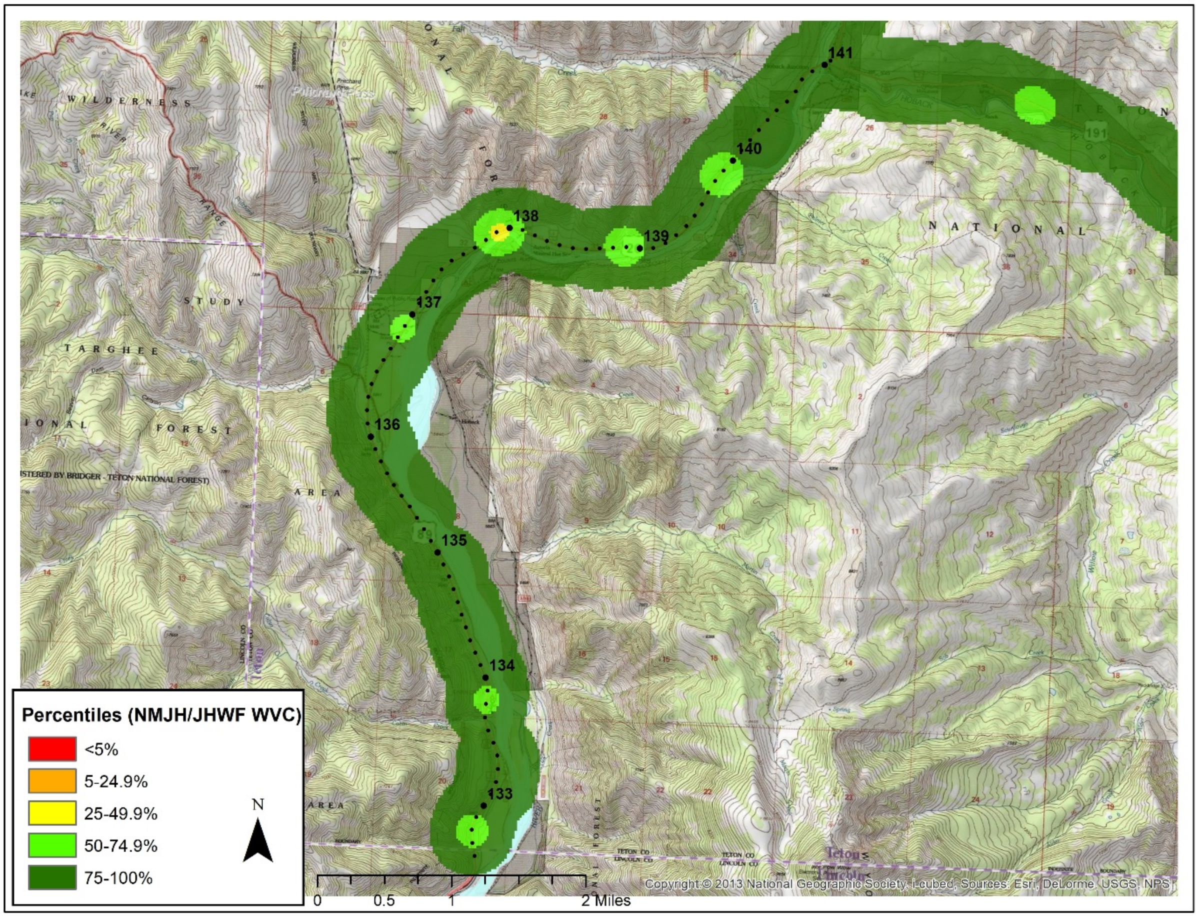
14. APPENDIX C: WILDLIFE-VEHICLE COLLISION HOTSPOTS NMJH/JHWF

Wildlife-vehicle collisions (Nature Mapping Jackson Hole, Jackson Hole Wildlife Foundation, 2017a)

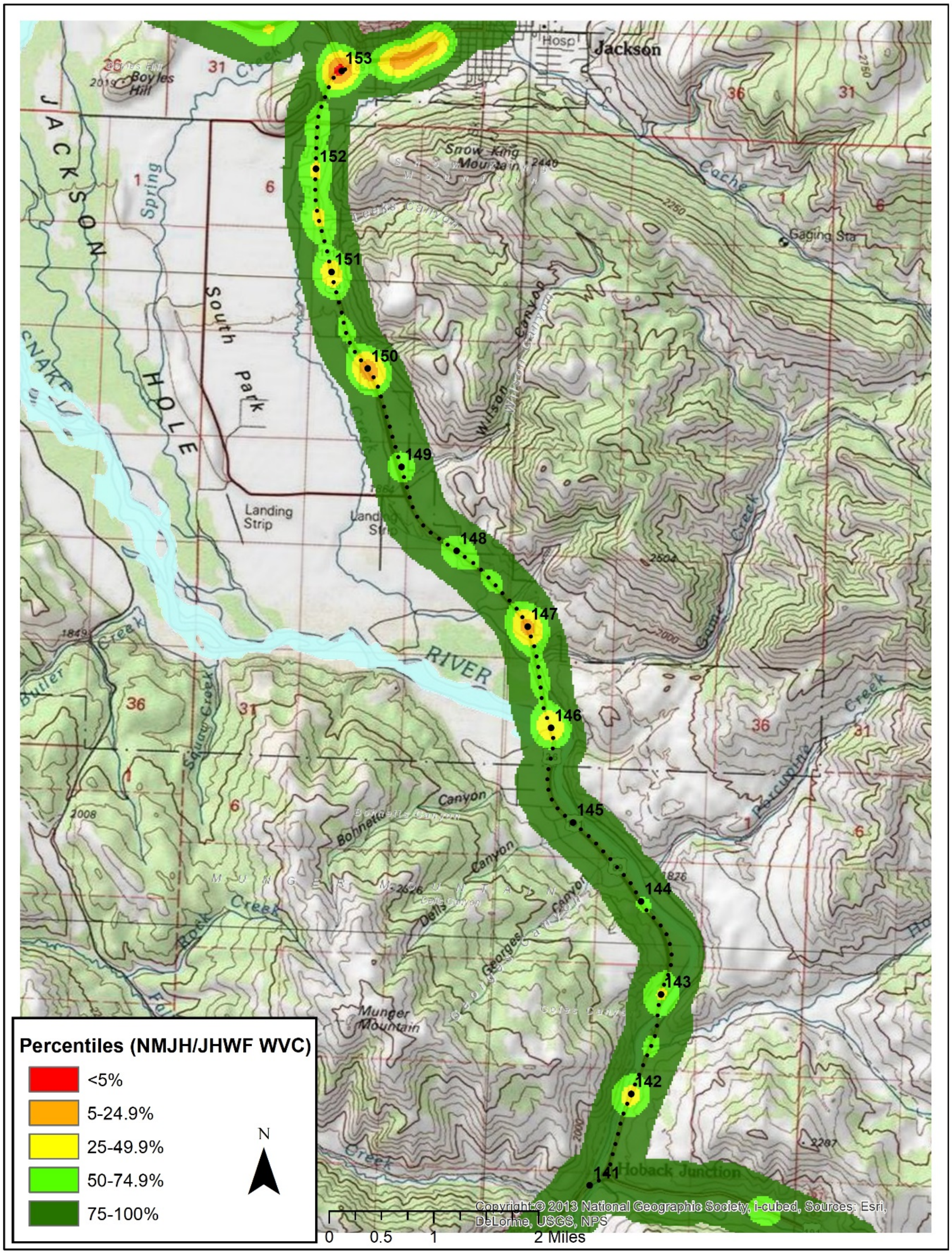
1. US Hwy 189/191



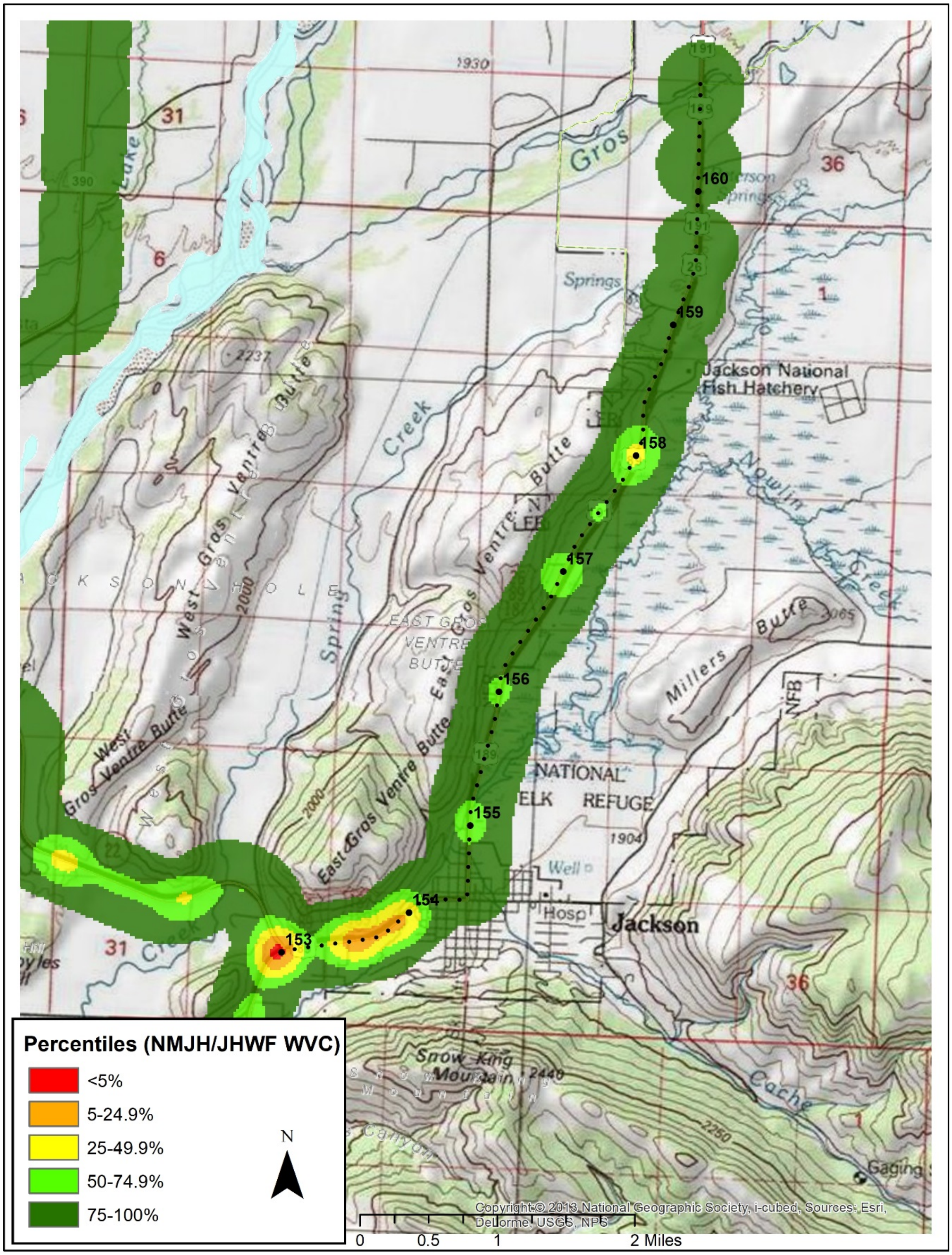
2. US Hwy 89/26


141
140
138
139
137
136
135
134
133
Percentiles (NMJH/JHWF WVC)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
Copyright © 2013 National Geographic Society, i-cubed. Sources: Esri, DeLorme, USGS, NPS

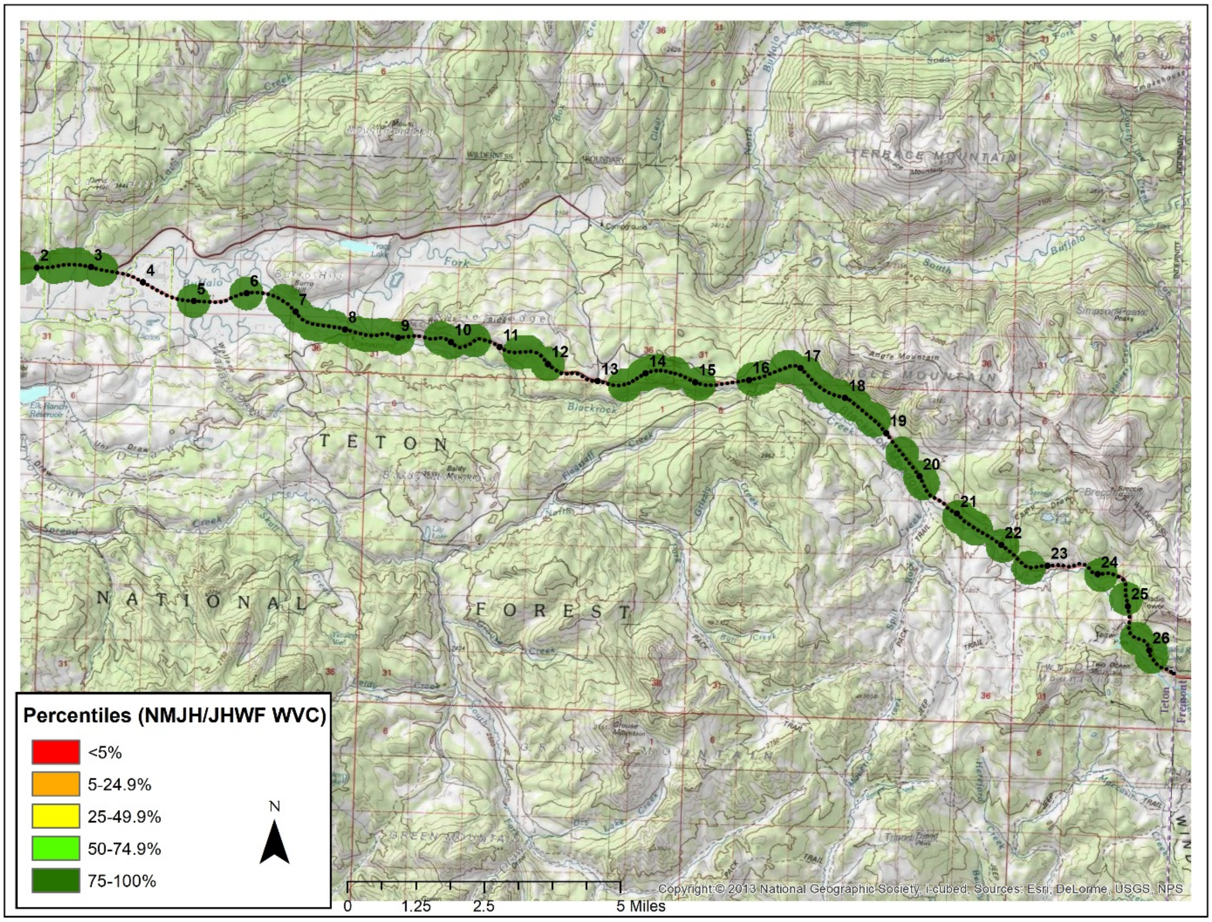
3. US Hwy 26/89/191



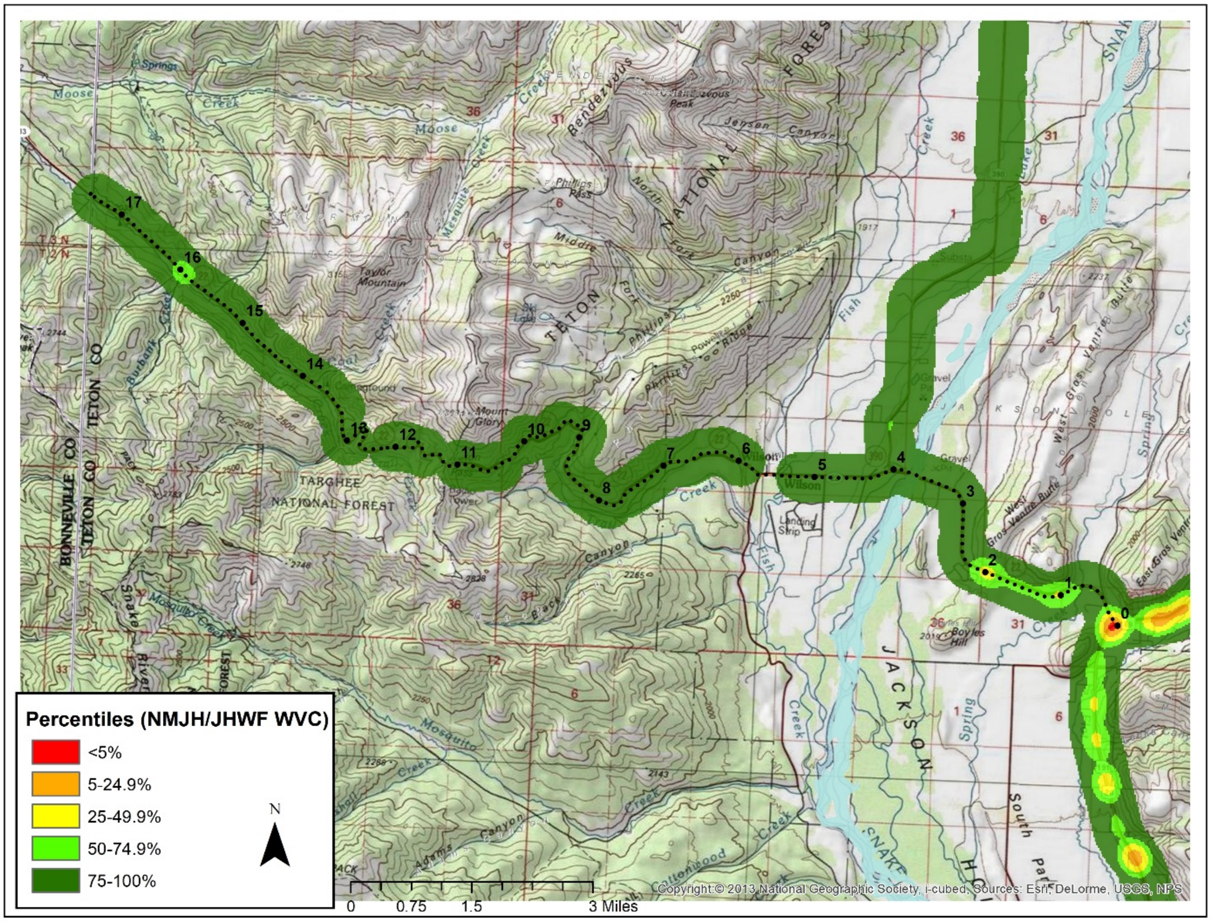
4. US Hwy 26/89/191



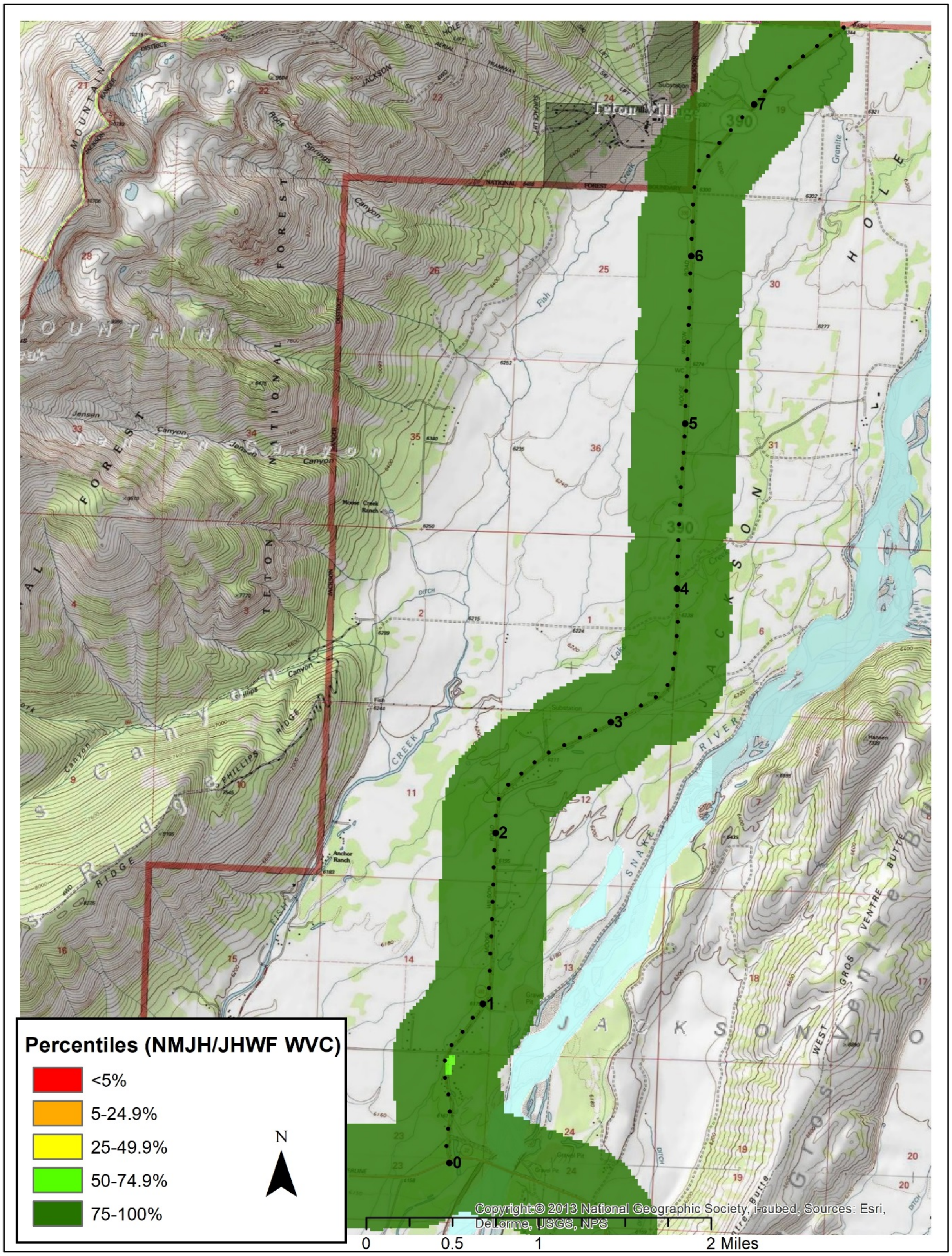
5. US Hwy 26/287



6. WY 22


Percentiles (NMJH/JHWF WVC)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0 0.75 1.5 3 Miles
Copyright © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

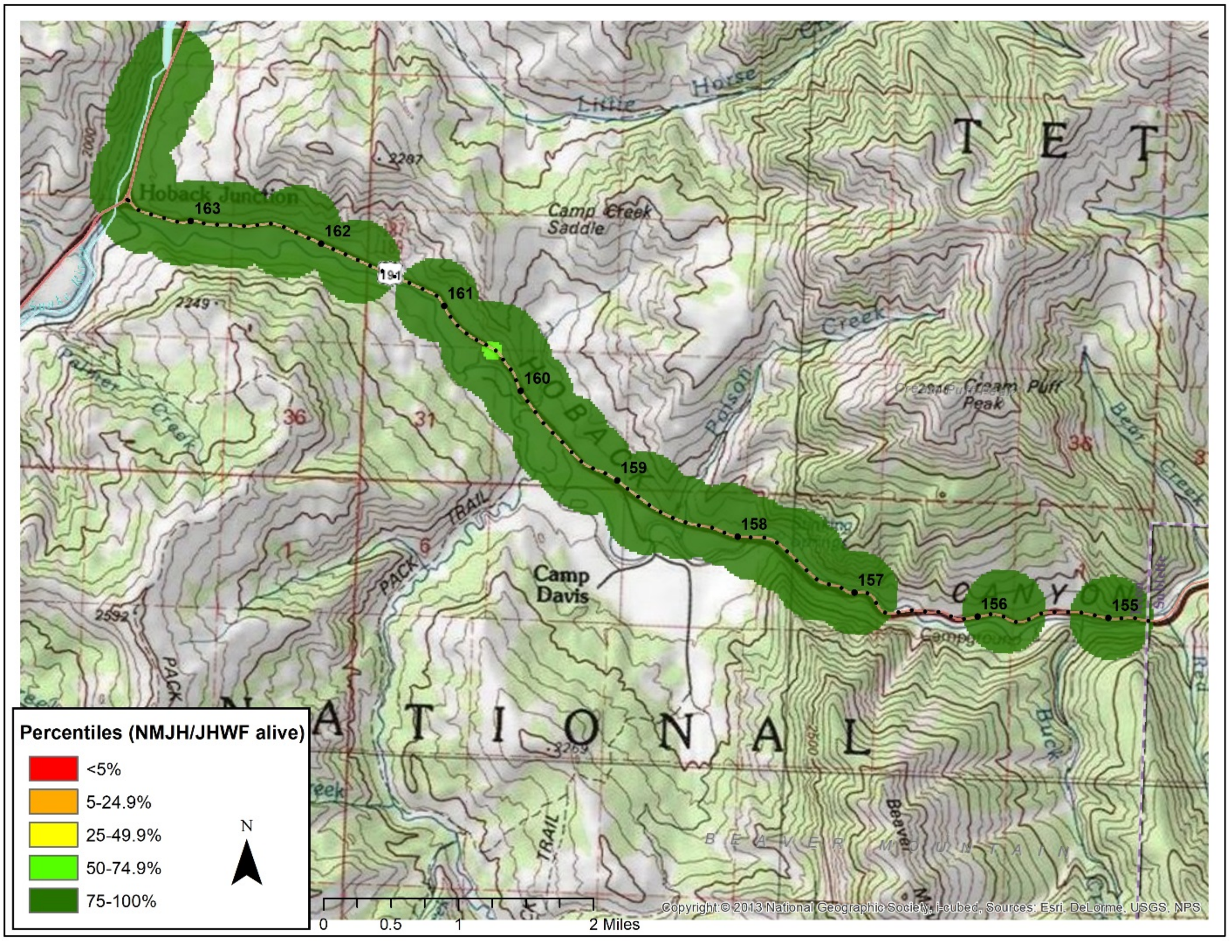
7. WY 390


Percentiles (NMJH/JHWF WVC)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
Copyright: © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS
0
0.5
1
2 Miles
0
1
2
3
4
5
6
7
Teton Village
390

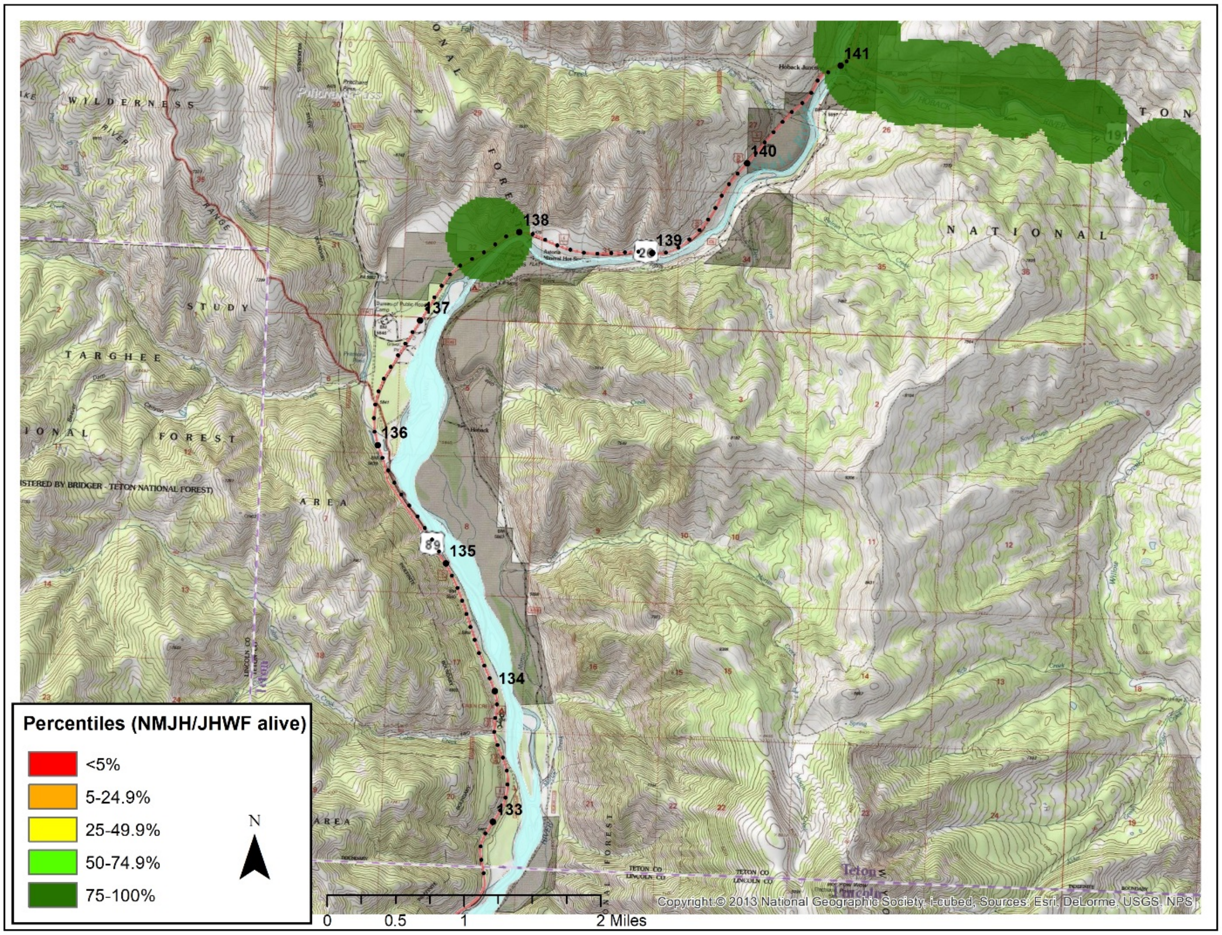
15. APPENDIX D: WILDLIFE OBSERVATION HOTSPOTS (ALIVE) NMJH/JHWF

Wildlife observations within 100 m from highways (Nature Mapping Jackson Hole, Jackson Hole Wildlife Foundation, 2017b).

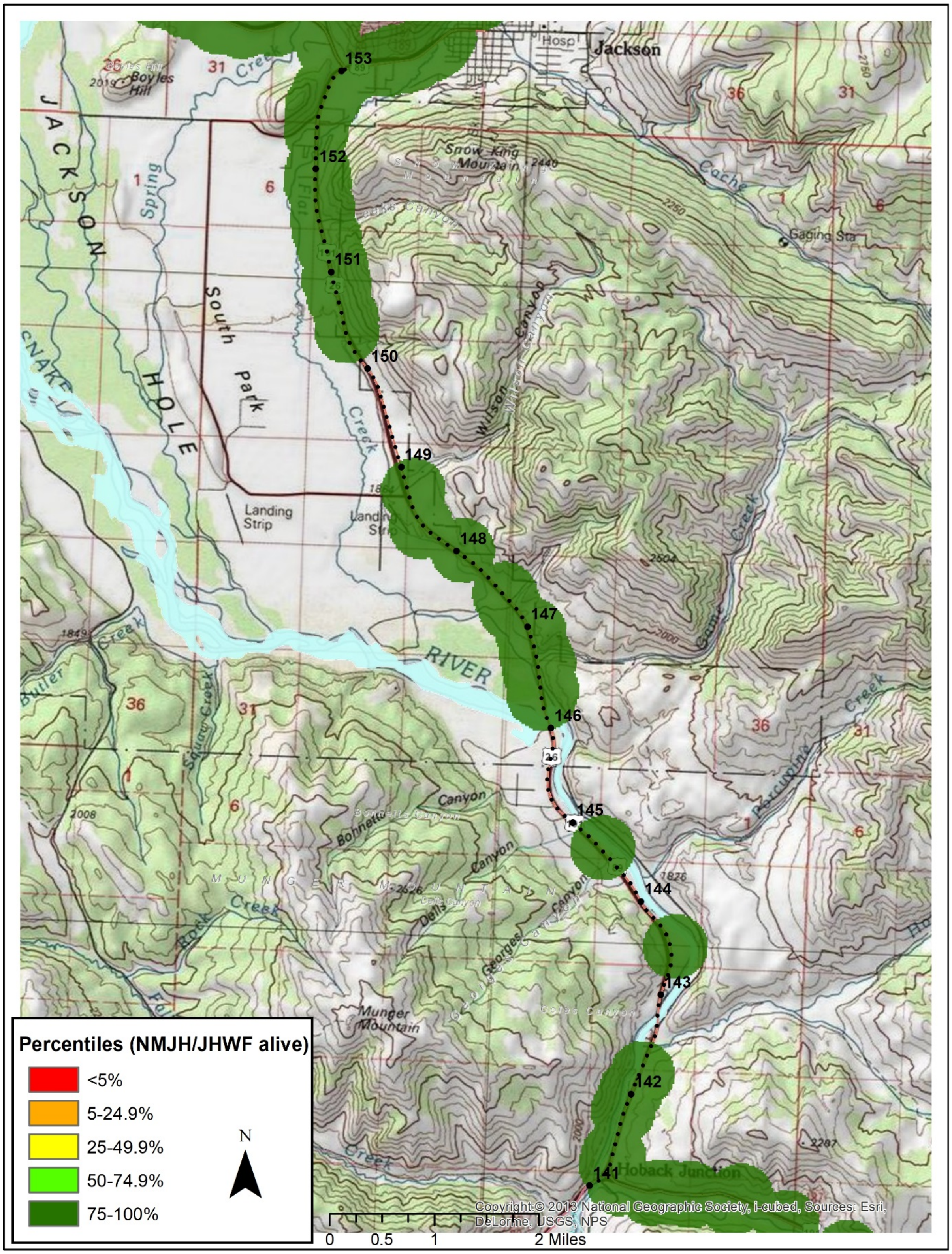
1. US Hwy 189/191



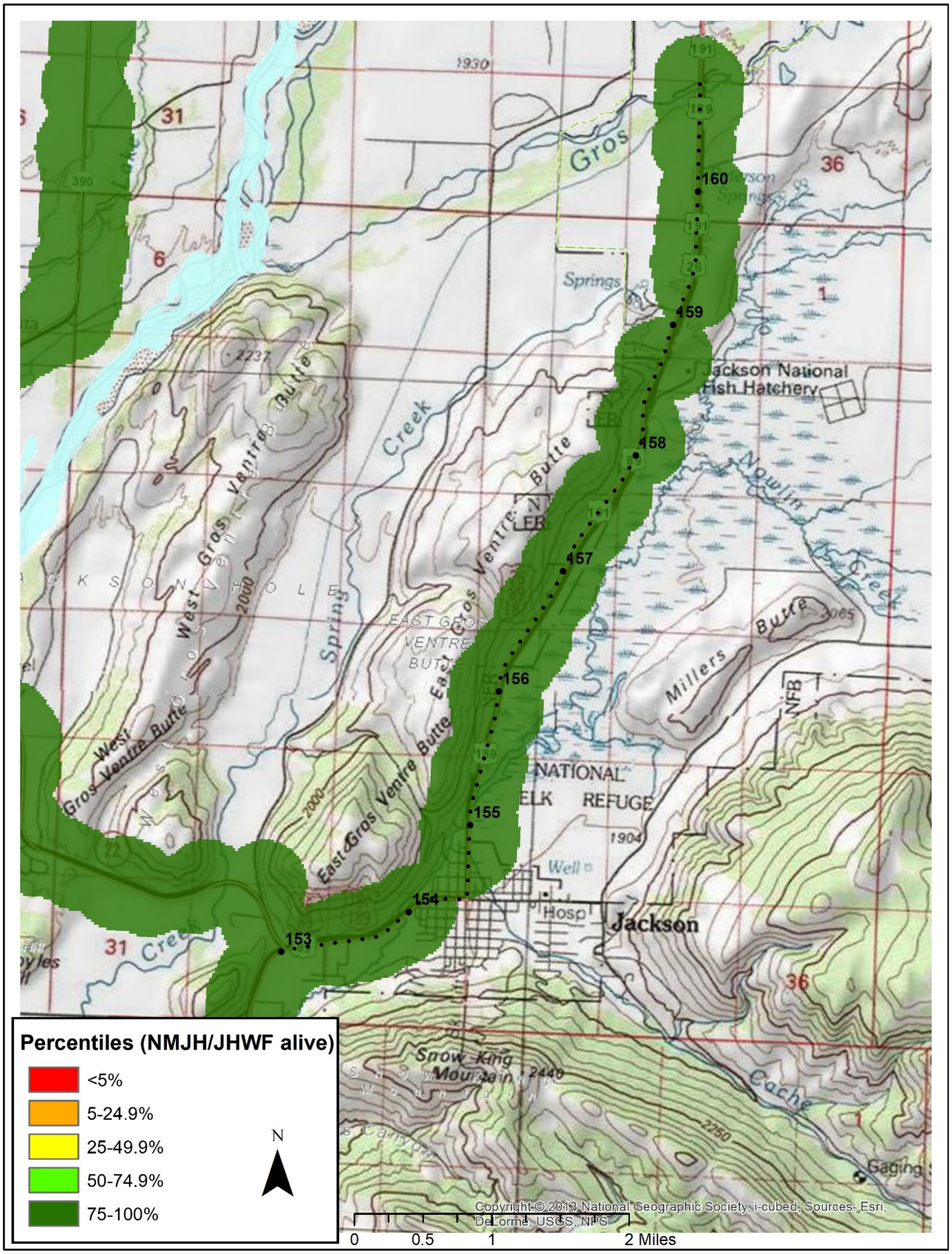
2. US Hwy 89/26


Percentiles (NMJH/JHWF alive)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
133
134
135
136
137
138
139
140
141
Copyright © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

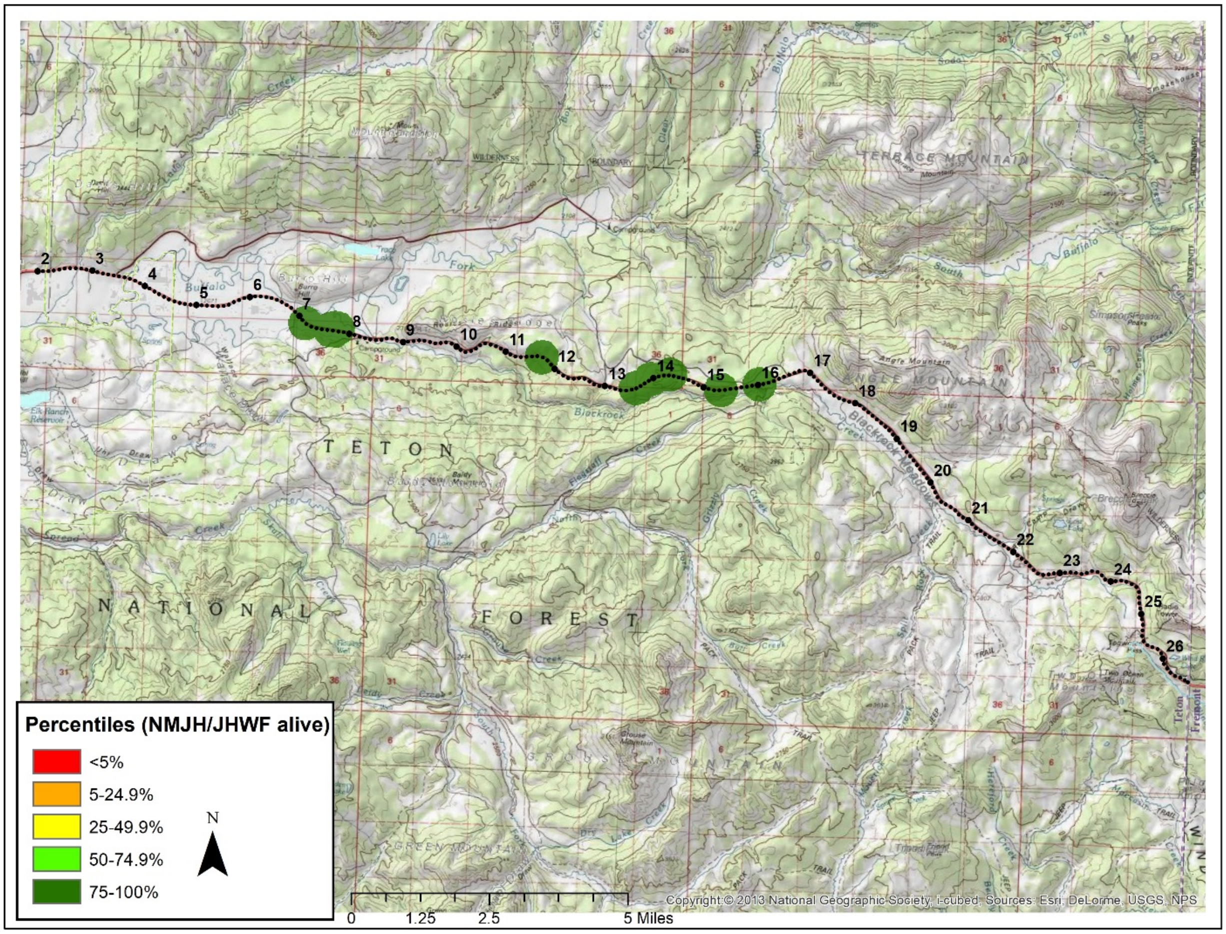
3. US Hwy 26/89/191



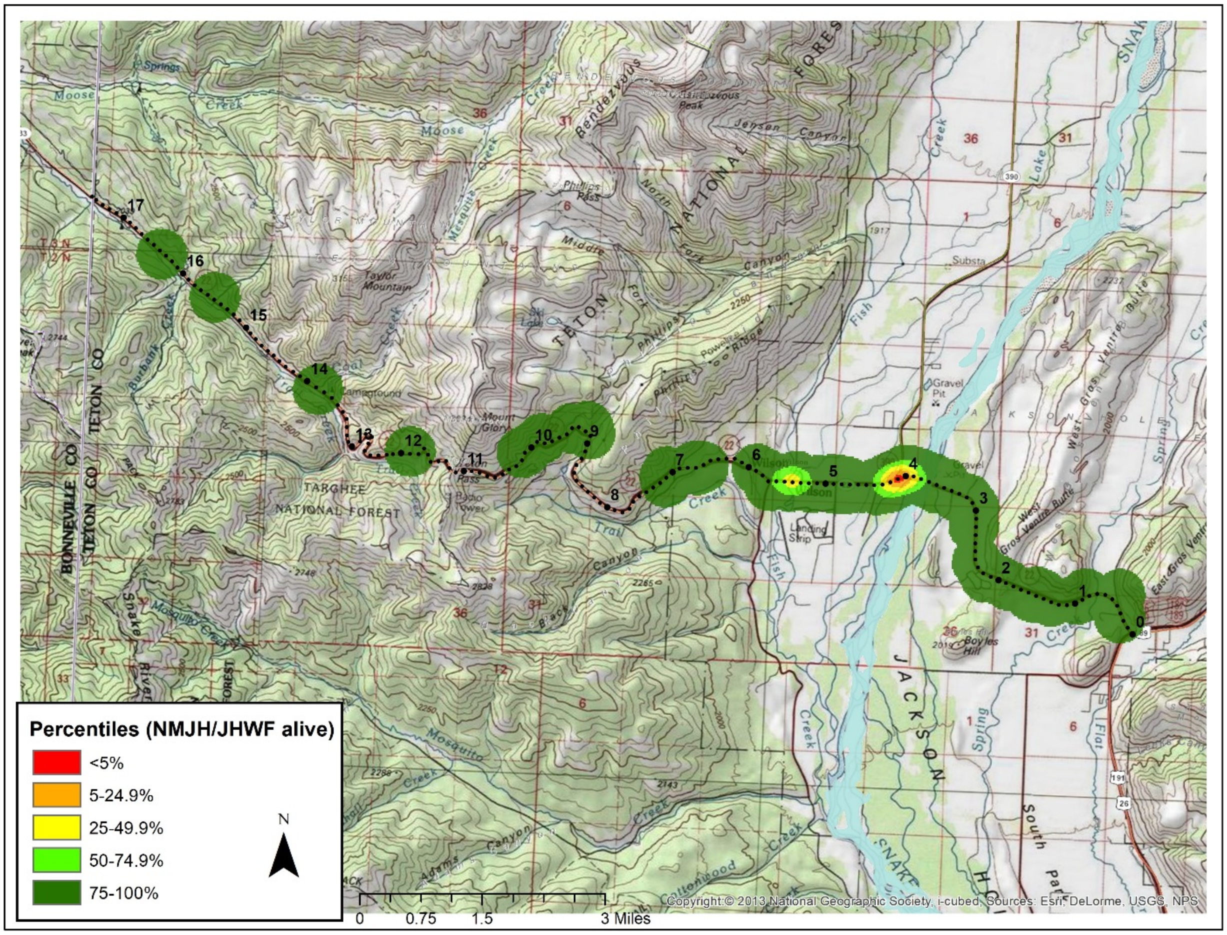
4. US Hwy 26/89/191



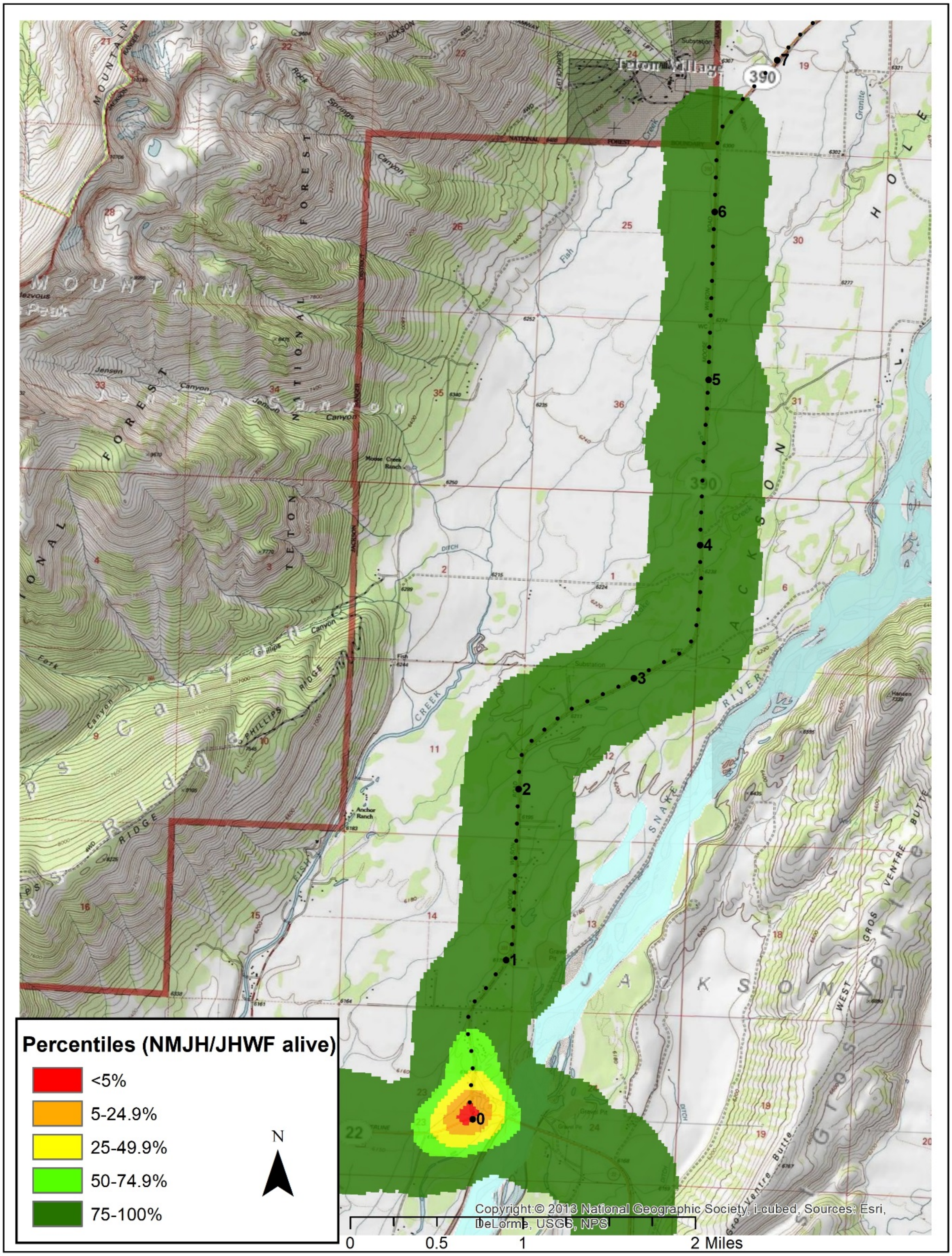
5. US Hwy 26/287



6. WY 22


Percentiles (NMJH/JHWF alive)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0 0.75 1.5 3 Miles
Copyright © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

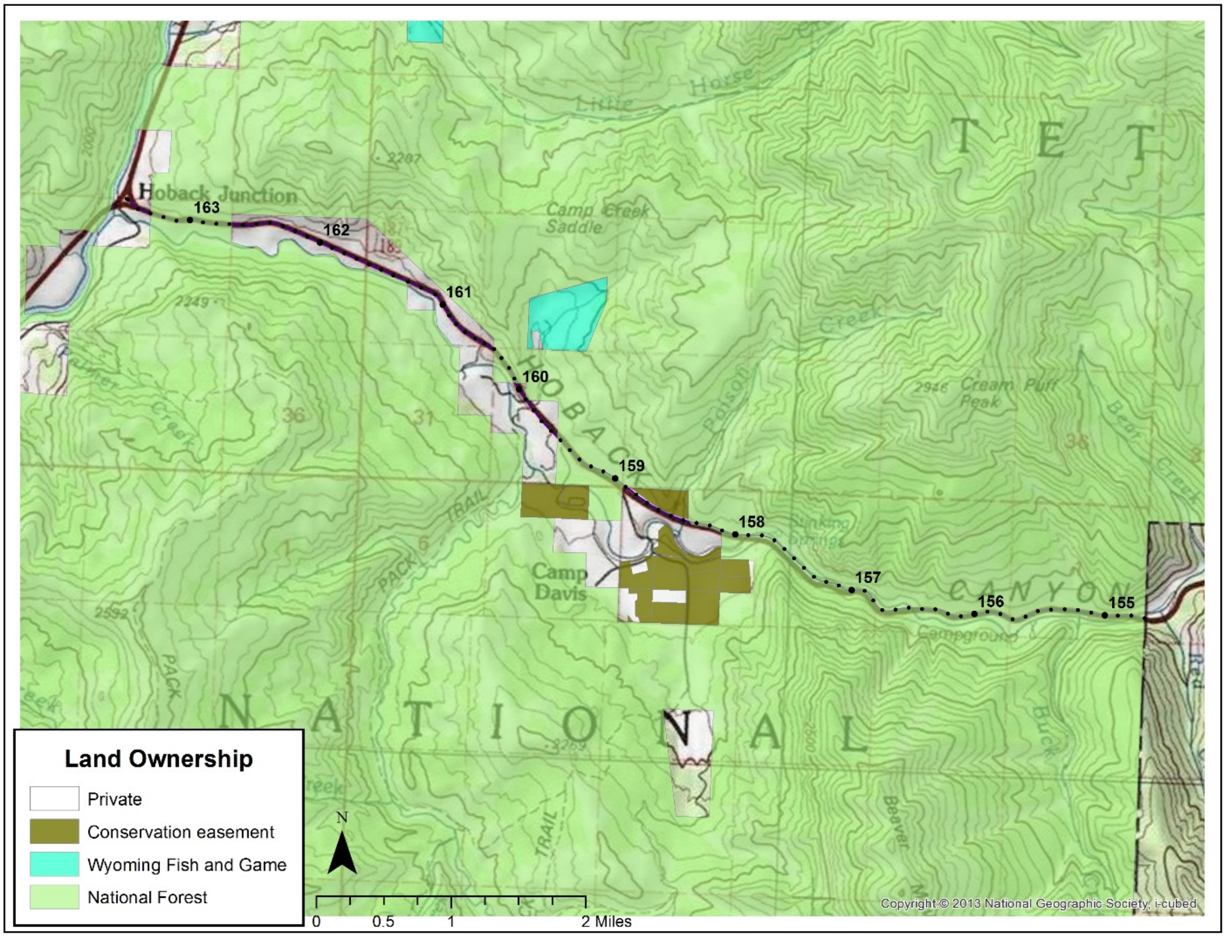
7. WY 390


Percentiles (NMJH/JHWF alive)
<5%
5-24.9%
25-49.9%
50-74.9%
75-100%
N
0
0.5
1
2 Miles
Copyright:© 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS
Teton Village
390

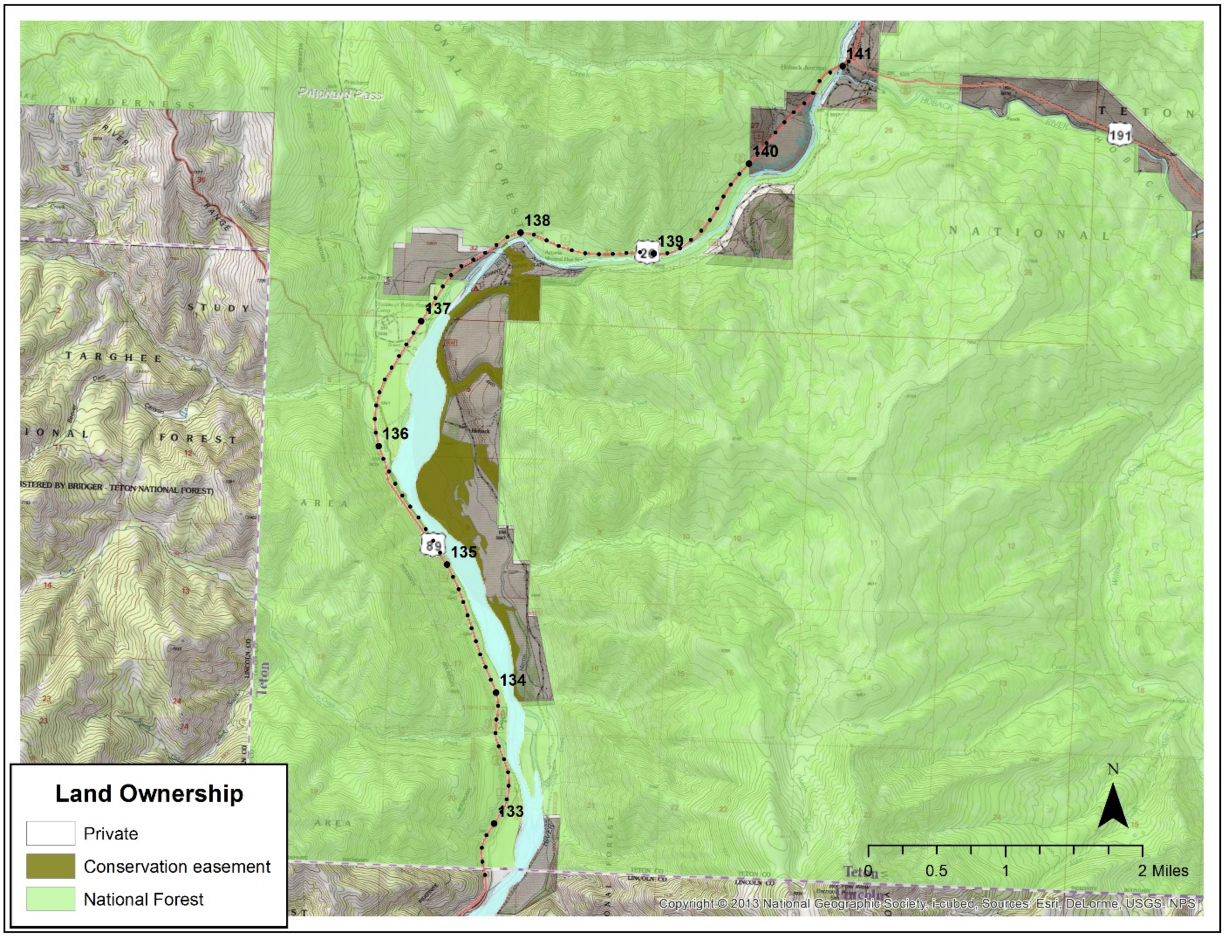
16.APPENDIX E: LAND OWNERSHIP

Note: The land ownership maps are indicative only. Check the following website of Teton County for the most up to date information on land ownership: https://maps.greenwoodmap.com/tetonwy/mapserver/map#zcr=4/2428680/1418580/0&lyrs=state_fed,water,tojcorp,Roads,ownership,placelabels

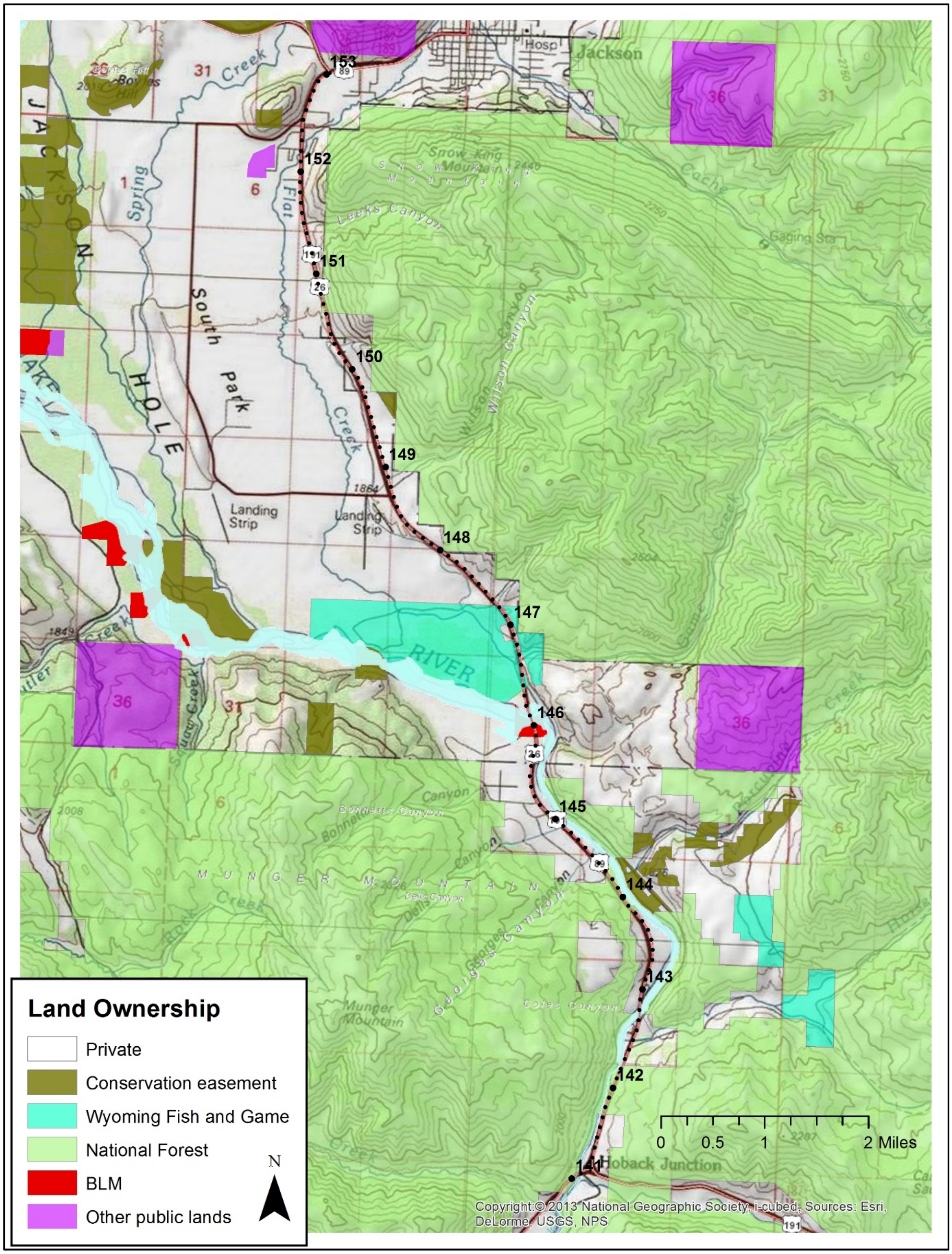
1. US Hwy 189/191



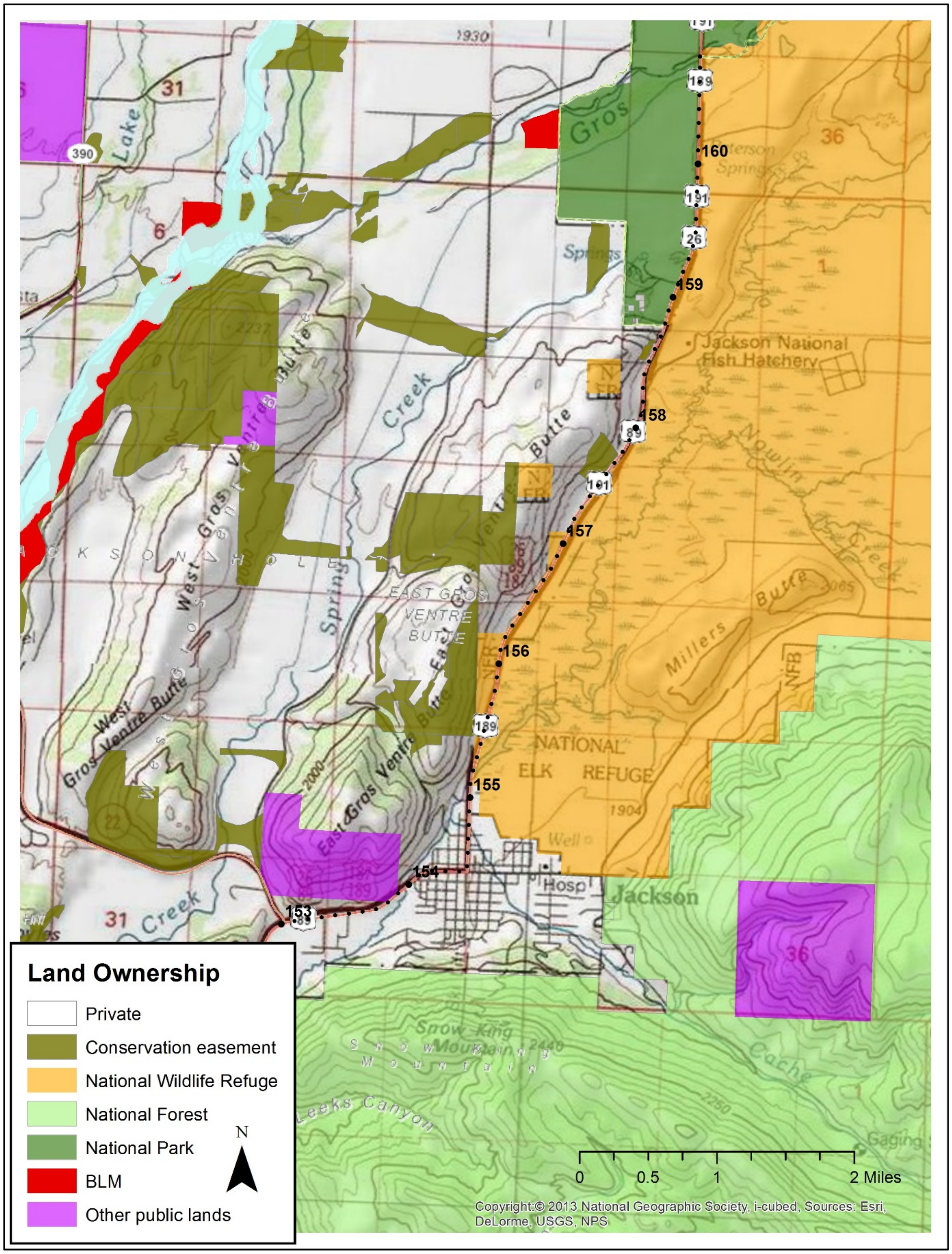
2. US Hwy 89/26


Land Ownership
Private
Conservation easement
National Forest
133
134
135
136
137
138
139
140
141
N
0
0.5
1
2 Miles
Copyright © 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

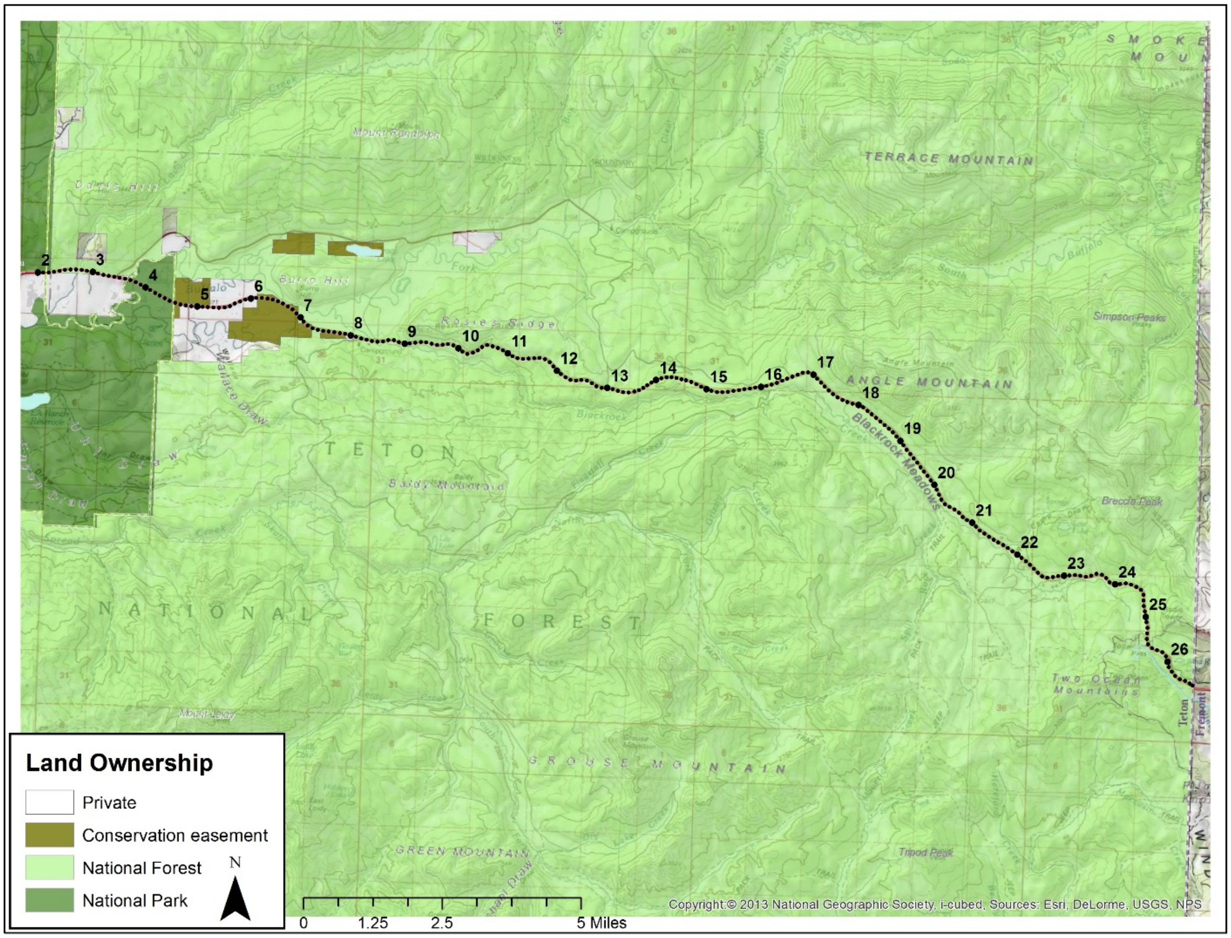
3. US Hwy 26/89/191



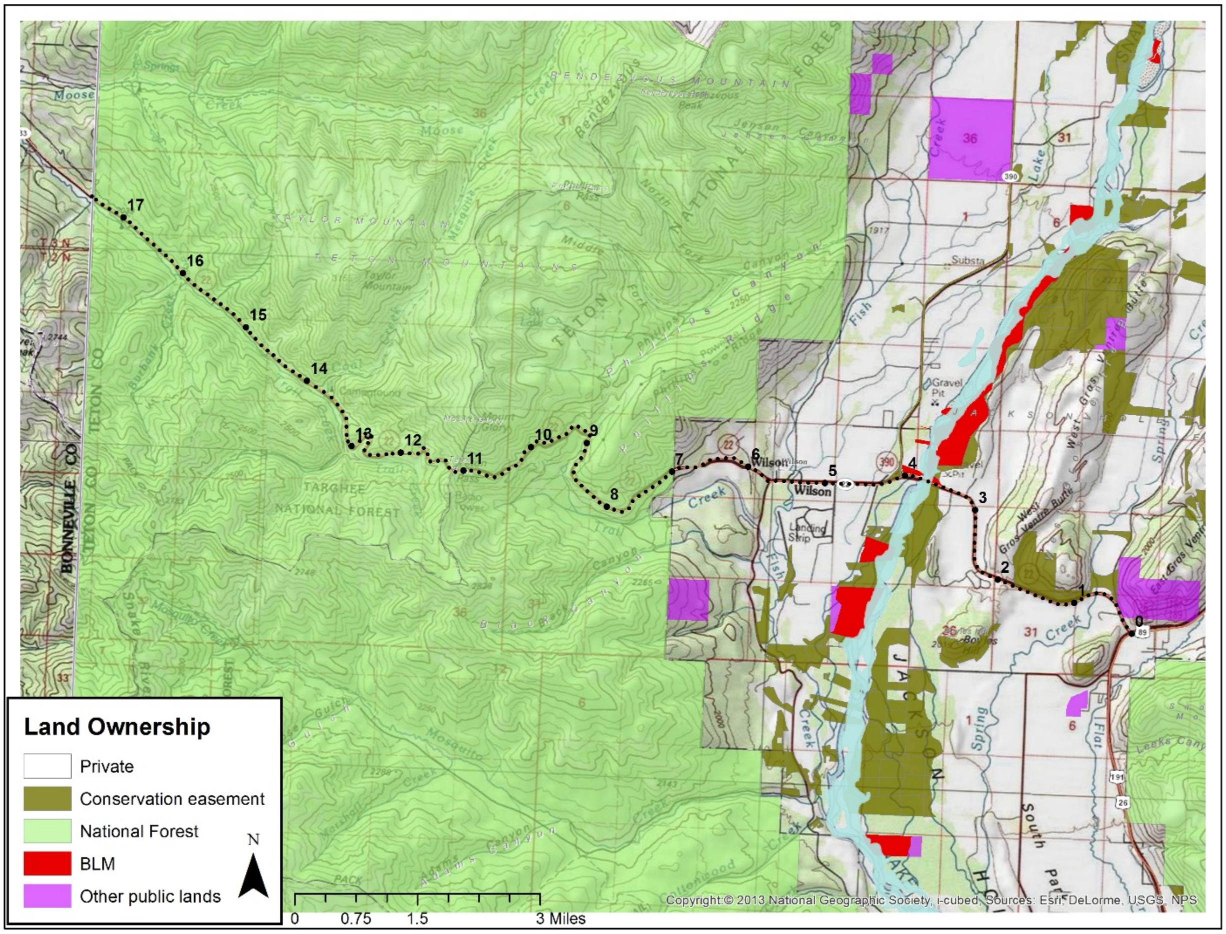
4. US Hwy 26/89/191



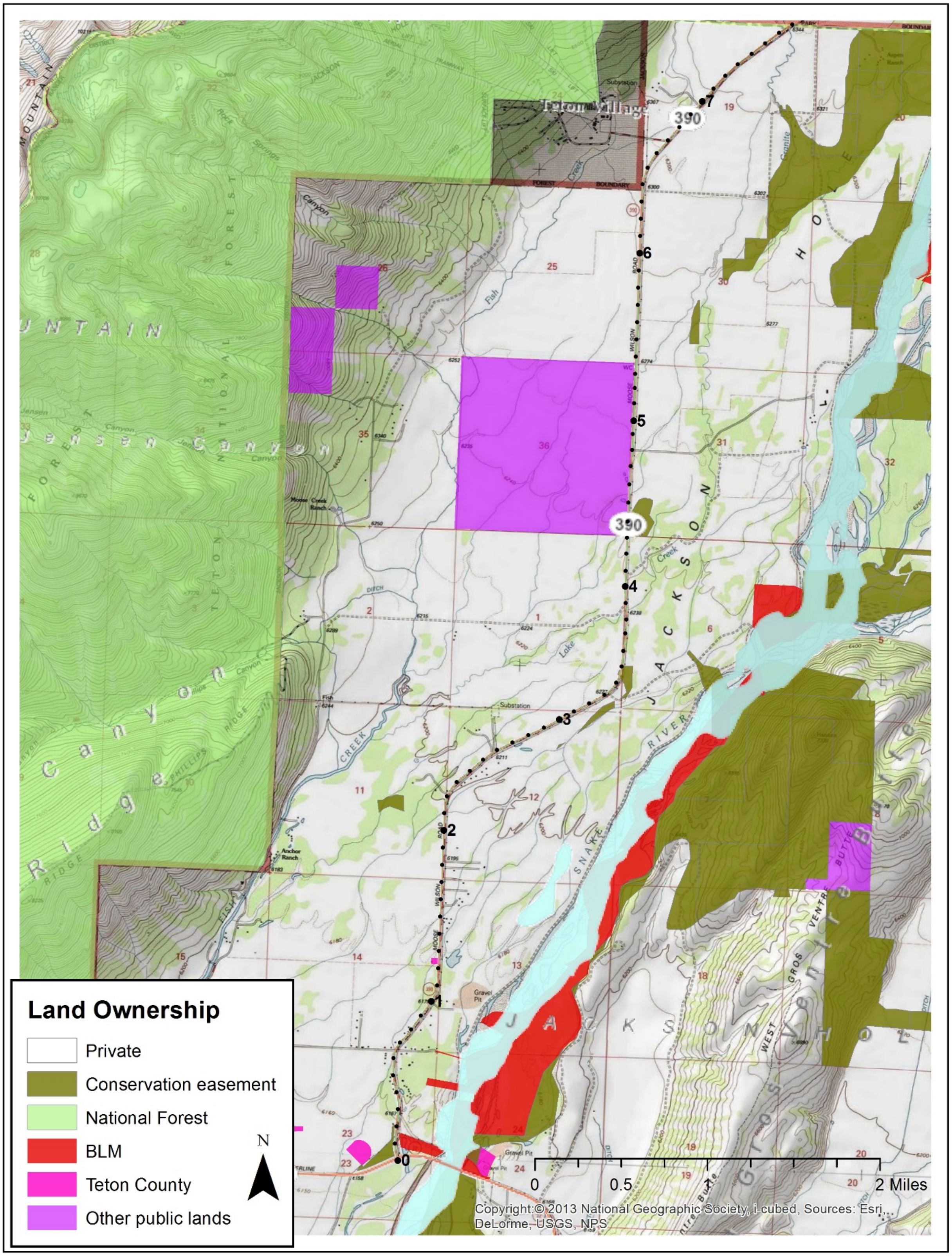
5. US Hwy 26/287



6. WY 22

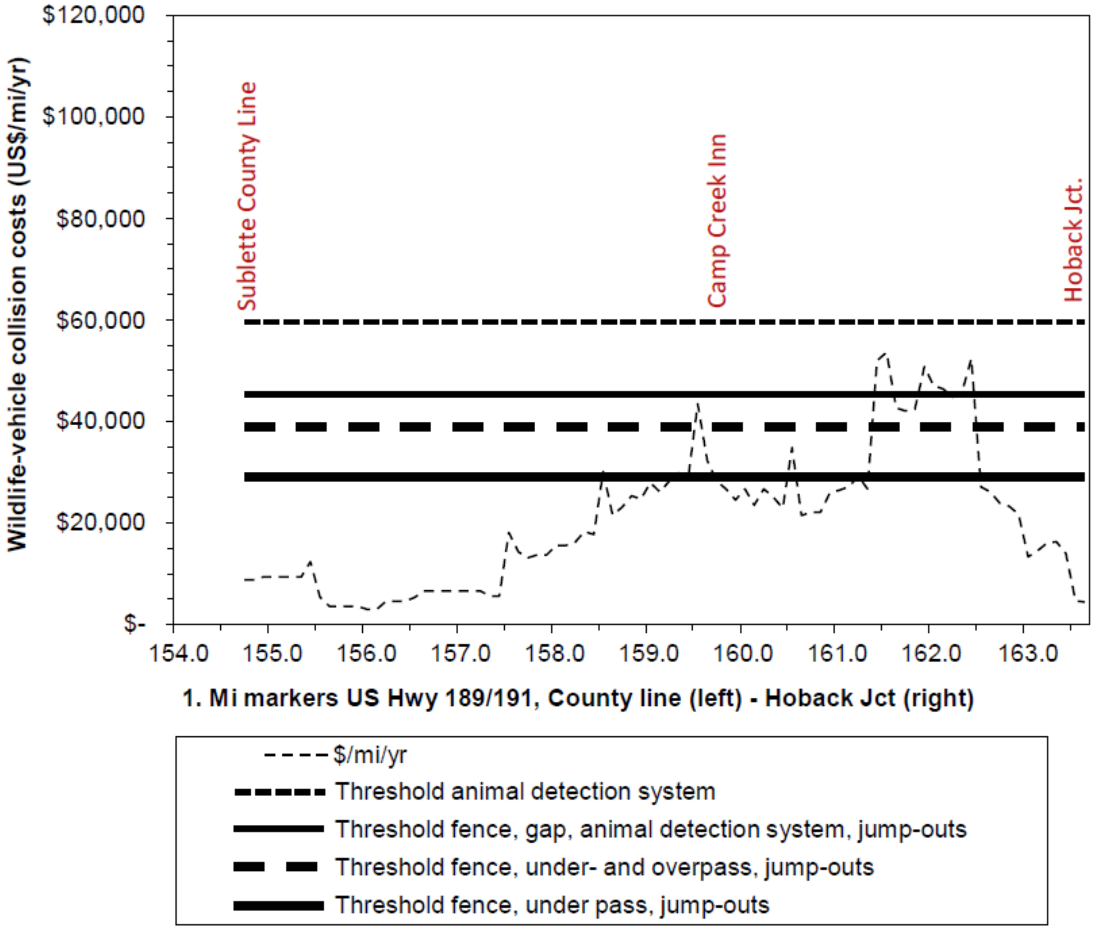

Land Ownership
Private
Conservation easement
National Forest
BLM
Other public lands
N
0 0.75 1.5 3 Miles
Wilson
Copyright:© 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS

7. WY 390

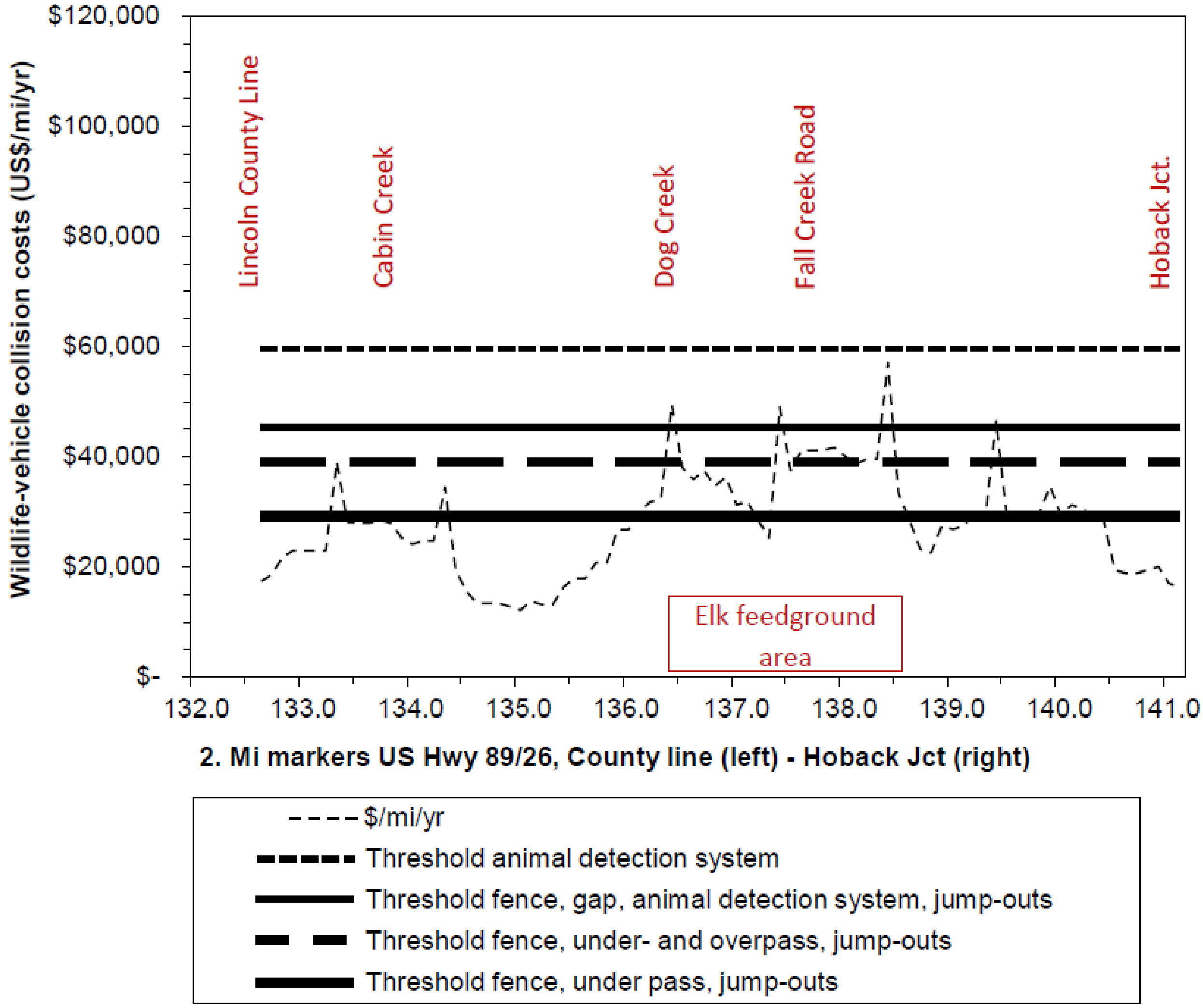

Land Ownership
Private
Conservation easement
National Forest
BLM
Teton County
Other public lands
N
0
0.5
1
2 Miles
Copyright:© 2013 National Geographic Society, i-cubed, Sources: Esri, DeLorme, USGS, NPS
390
Teton Village
0
1
2
3
4
5
6
7

17.APPENDIX F: RAW OUTPUT COST-BENEFIT ANALYSES PER ROAD SECTION

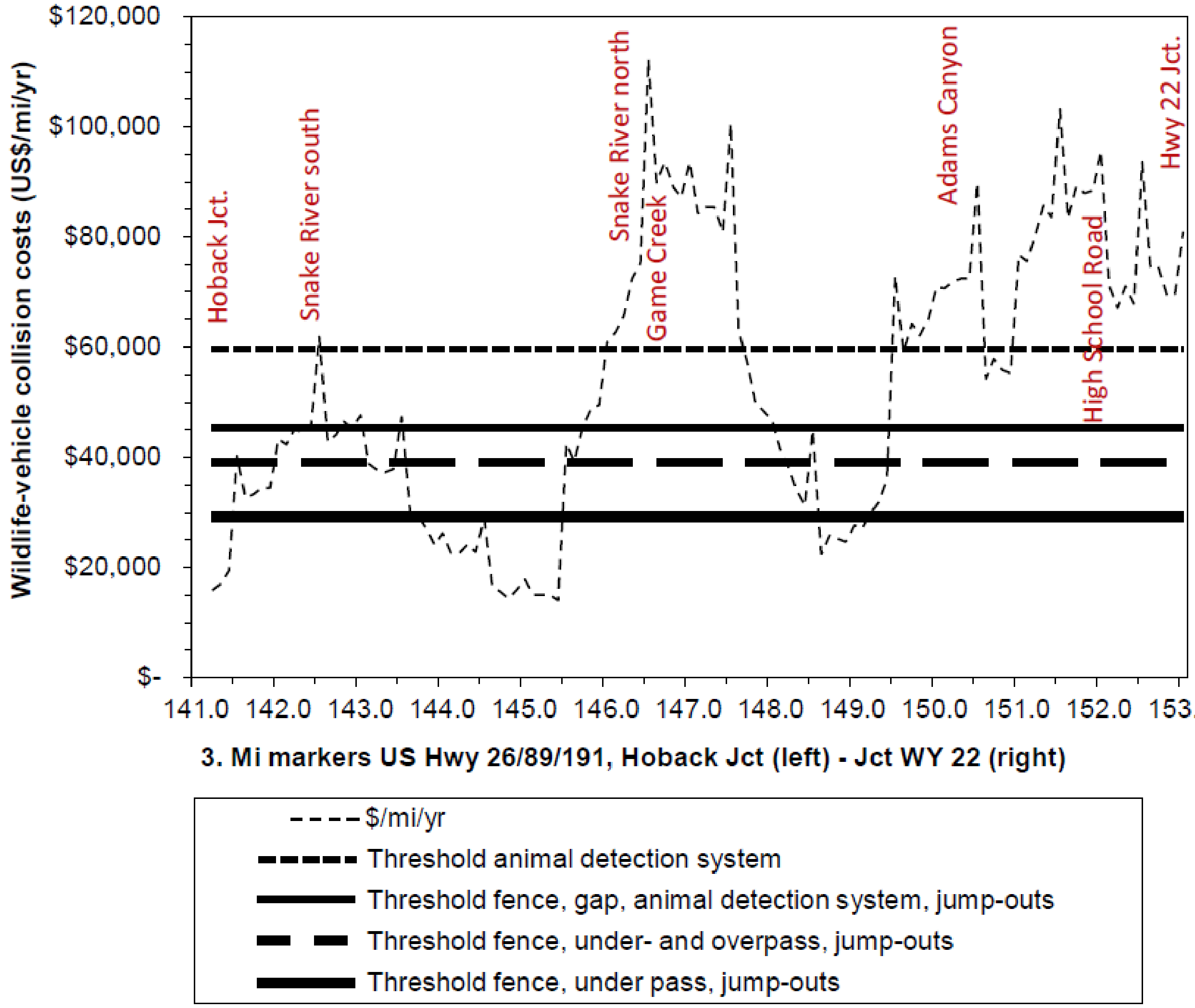
1. US Hwy 189/191



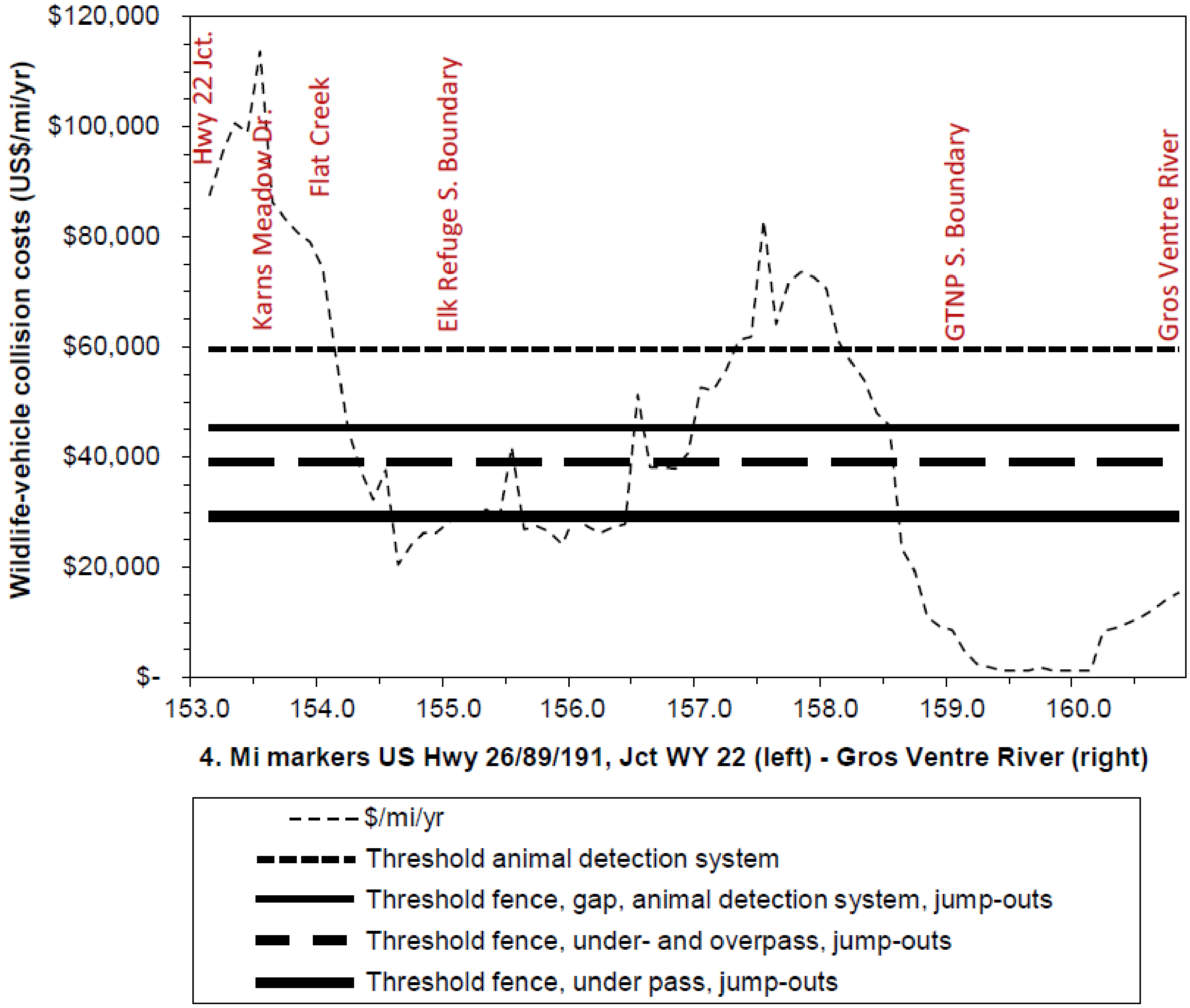
2. US Hwy 89/26


$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
Wildlife-vehicle collision costs (US$/mi/yr)
Lincoln County Line
Cabin Creek
Dog Creek
Fall Creek Road
Hoback Jct.
Elk feedground area
132.0
133.0
134.0
135.0
136.0
137.0
138.0
139.0
140.0
141.0
2. Mi markers US Hwy 89/26, County line (left) - Hoback Jct (right)
$/mi/yr
Threshold animal detection system
Threshold fence, gap, animal detection system, jump-outs
Threshold fence, under- and overpass, jump-outs
Threshold fence, under pass, jump-outs

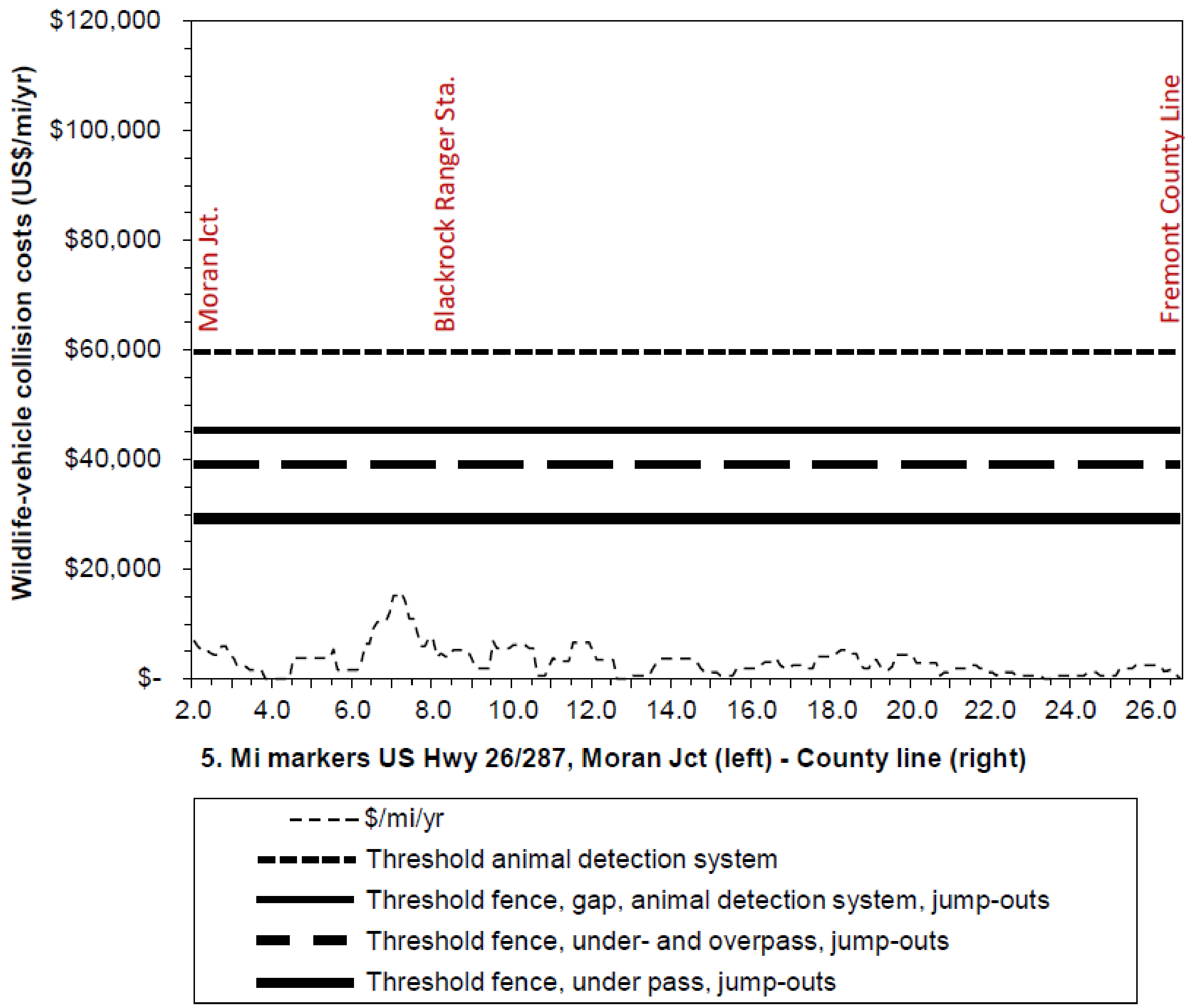
3. US Hwy 26/89/191



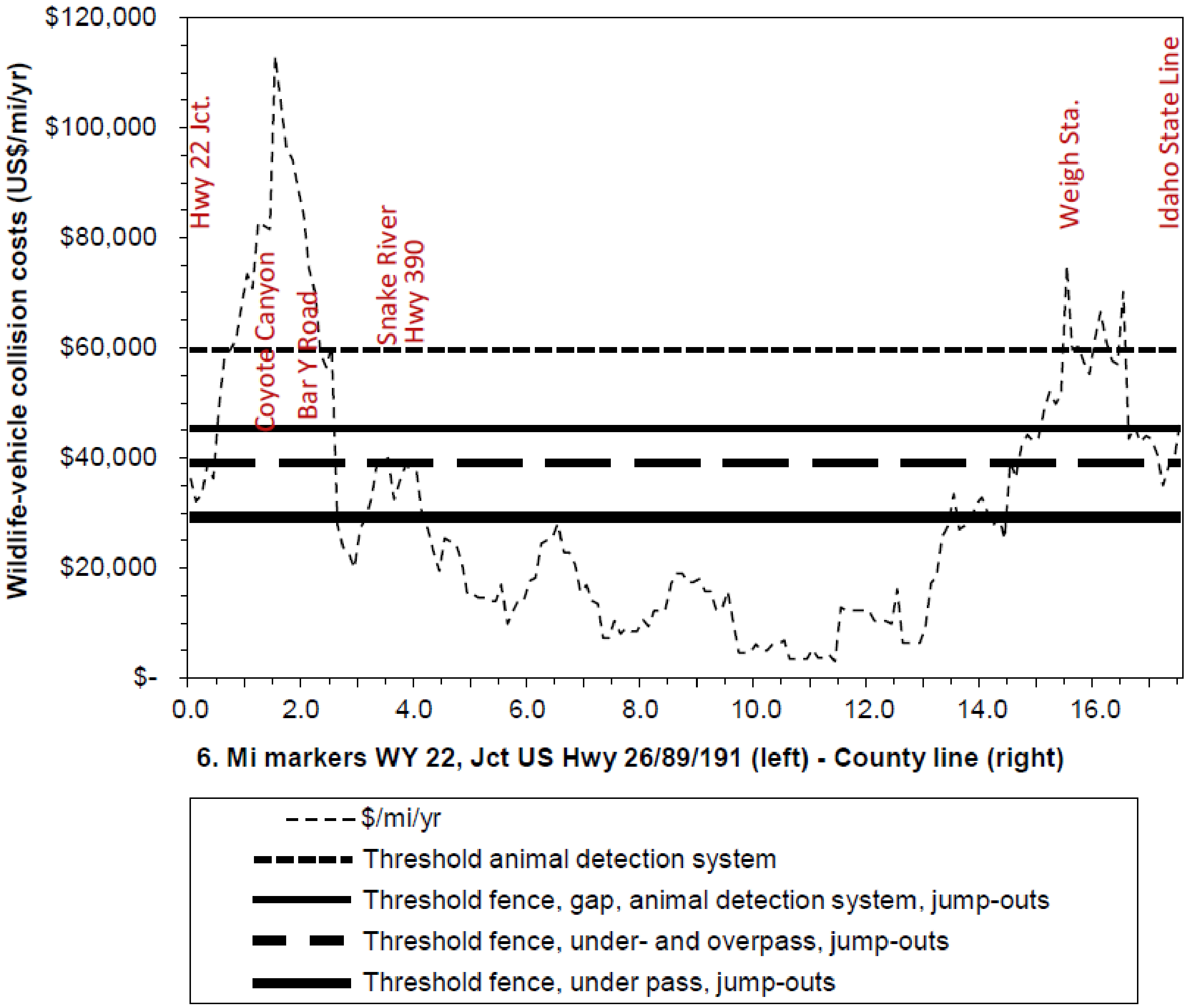
4. US Hwy 26/89/191



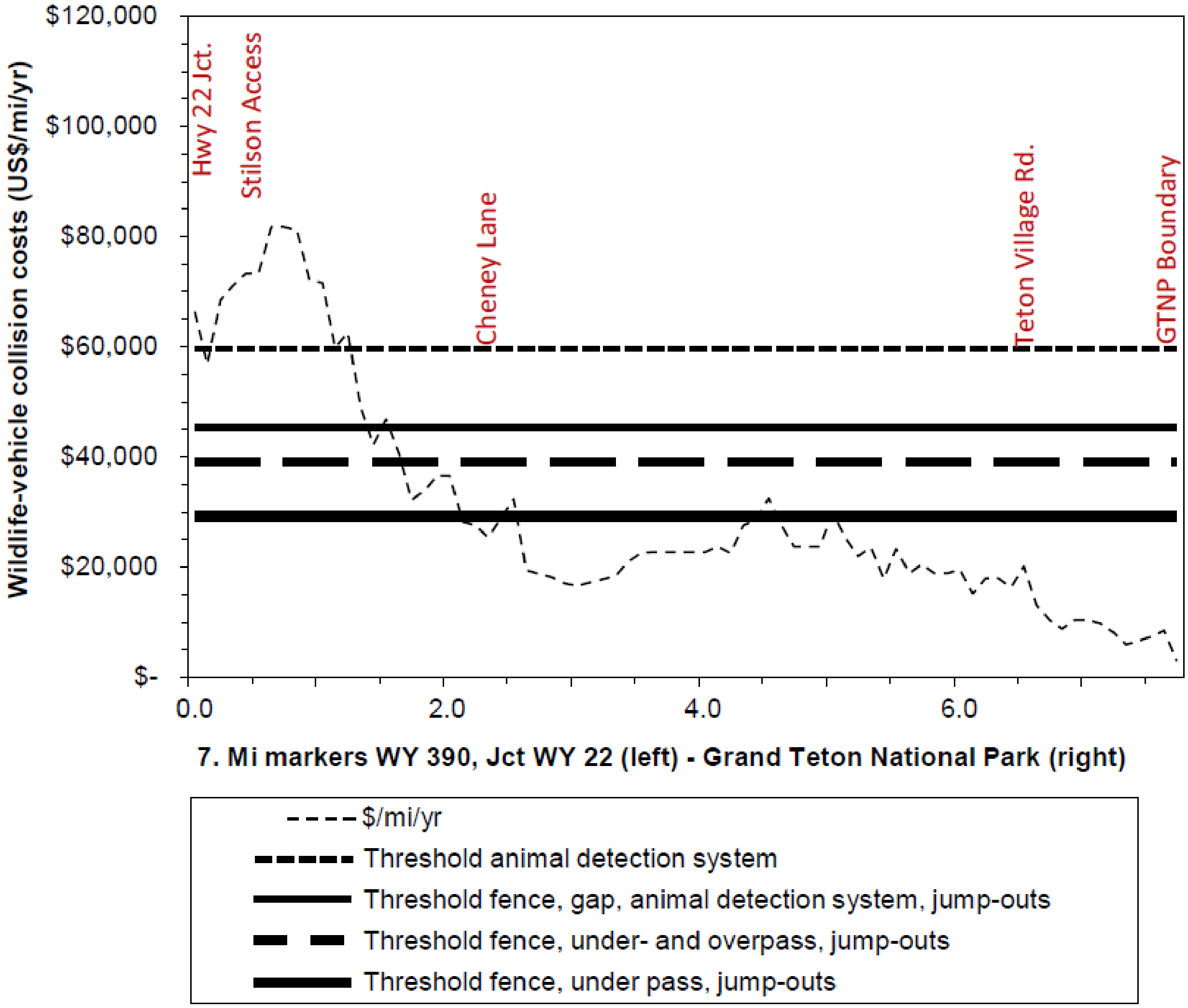
5. US Hwy 26/287



6. WY 22


$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
Wildlife-vehicle collision costs (US$/mi/yr)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Hwy 22 Jct.
Coyote Canyon
Bar Y Road
Snake River
Hwy 390
Weigh Sta.
Idaho State Line
6. Mi markers WY 22, Jct US Hwy 26/89/191 (left) - County line (right)
$/mi/yr
Threshold animal detection system
Threshold fence, gap, animal detection system, jump-outs
Threshold fence, under- and overpass, jump-outs
Threshold fence, under pass, jump-outs

7. WY 390


$120,000
$100,000
$80,000
$60,000
$40,000
$20,000
$-
Wildlife-vehicle collision costs (US$/mi/yr)
Hwy 22 Jct.
Stilson Access
Cheney Lane
Teton Village Rd.
GTNP Boundary
0.0
2.0
4.0
6.0
7. Mi markers WY 390, Jct WY 22 (left) - Grand Teton National Park (right)
$/mi/yr
Threshold animal detection system
Threshold fence, gap, animal detection system, jump-outs
Threshold fence, under- and overpass, jump-outs
Threshold fence, under pass, jump-outs

18. APPENDIX G: LANDMARKS ASSOCIATED WITH MILE REFERENCE POINTS

Provided by Amy Ramage (Teton County).

Section 1		
SUBLETTE COUNTY TO HOBACK JCT.		
"TO HOBACK CANYON"		
	MP	LANDMARK
EAST	154.75	SUBLETTE COUNTY LINE
	157.96	HOBACK RIVER NEAR STINKING SPRINGS
	159.85	CAMP CREEK INN
WEST	163.67	HOBACK JCT.
Section 2		
LINCOLN COUNTY TO HOBACK JCT.		
"TO SNAKE RIVER CANYON"		
	MP	LANDMARK
SOUTH	132.62	LINCOLN COUNTY LINE
	133.71	CABIN CREEK
	136.23	DOG CREEK
	137.02	FALL CREEK ROAD
	137-138	HOBACK ELK FEEDGROUND AREA
	138.2	Astoria Hot Springs/SRSC
	140.6	FALL CREEK
	141.08	SNAKE RIVER
NORTH	141.31	HOBACK JCT.
Section 3		
HOBACK JCT. TO HWY 22 INTERSECTION		
"SOUTH HWY 89"		
	MP	LANDMARK
SOUTH	142.78	SNAKE RIVER
	145.25	WYDOT JACKSON OFFICE
	146.09	SNAKE RIVER
	146.39	FLAT CREEK
	146.73	GAME CREEK ROAD
	148.71	SOUTH PARK LOOP (SOUTHERN LEG)
	150.01	ADAMS CANYON DRIVE
	152.05	HIGH SCHOOL ROAD
	152.16	FLAT CREEK

NORTH	153.05	HWY 22
Section 4		
HWY 22 INTERSECTION TO GTNP		
"TOWN OF JACKSON & NORTH TO GTNP"		
	MP	LANDMARK
SOUTH	153.05	HWY 22
	153.68	KARNS MEADOW DRIVE
	153.98	FLAT CREEK
	154.93	JACKSON INFO CENTER
	154.98	S. BNDRY OF ELK REFUGE
	155.12	FLAT CREEK
	158.82	GTNP BOUNDARY
NORTH	160.73	GROS VENTRE RIVER
Section 5		
"TO TOGWOTEE PASS"		
	MP	LANDMARK
WEST	2.2	GTNP BOUNDARY
	8.1	BLACKROCK RANGER STATION
	16.5	TOGWOTEE LODGE
EAST	26.75	FREMONT COUNTY LINE
Section 6		
HIGHWAY 22		
	MP	LANDMARK
EAST	0	US 26/89/191 INTERSECTION
	0.66	SPRING GULCH ROAD
	1.67	TETON SCIENCE SCHOOL INTERSECTION
	2.05	BAR Y ROAD
	3.76	SNAKE RIVER
	4.06	WYO 390
	11.17	TOP OF TETON PASS
	13.73	COAL CREEK TRAILHEAD
	15.53	WEIGH STATION
	17.23	TRAIL CREEK CAMPGROUND
WEST	17.49	IDAHO STATELINE
Section 7		
HIGHWAY 390		
	MP	LANDMARK
SOUTH	0	HWY 22

	0.21	STILSON APPROACH
	2.26	CHENEY LANE
	3.84	GRANITE CREEK
	6.49	TETON VILLAGE ROAD
	7.55	GRANITE CREEK
NORTH	7.71	GTNP BOUNDARY

19. APPENDIX H: RAW DATA FOR THE HUMAN SAFETY, BIOLOGICAL CONSERVATION, AND ECONOMIC PARAMETERS PER 0.1 MI ROAD SECTION

			HUMAN SAFETY				BIOLOGICAL CONSERVATION						ECONOMICS	
ID	Mi reference post	Hwy section	Large wild mammal collisions	Deer collisions	Elk collisions	Moose collisions	NMJH/JHWF alive	Mule deer movement	Elk movement	Moose movement	Bighorn sheep	High elevation for large carnivores	Collisions ($/mi/yr)	Thresholds exceeded (N)
1	154.7	1			moderate		2	1	0	0	0	0	$8,812	
2	154.8	1			moderate		2	1	0	0	0	0	$8,812	
3	154.9	1			moderate		2	1	0	0	0	0	$9,413	
4	155.0	1					2	1	0	0	0	0	$9,413	
5	155.1	1					2	1	0	0	0	0	$9,413	
6	155.2	1					2	1	0	0	0	0	$9,413	
7	155.3	1					1	1	0	0	0	0	$9,413	
8	155.4	1					1	1	0	0	0	0	$12,421	
9	155.5	1					2	1	0	0	0	0	$5,414	
10	155.6	1					2	1	0	0	0	0	$3,609	
11	155.7	1					2	1	0	0	0	0	$3,609	
12	155.8	1					2	1	0	0	0	0	$3,609	
13	155.9	1					2	1	0	0	0	0	$3,609	
14	156.0	1					2	1	0	0	0	0	$3,008	
15	156.1	1					1	1	0	0	0	0	$3,008	
16	156.2	1					1	1	0	0	0	0	$4,597	
17	156.3	1					1	1	0	0	0	0	$4,597	
18	156.4	1					1	1	0	0	0	0	$4,597	
19	156.5	1					1	1	0	0	0	0	$5,370	
20	156.6	1					1	1	0	0	0	0	$6,573	
21	156.7	1					2	1	0	0	0	0	$6,573	
22	156.8	1					2	1	0	0	0	0	$6,573	
23	156.9	1					2	1	0	0	0	0	$6,573	
24	157.0	1			high		2	1	0	0	0	0	$6,573	
25	157.1	1			high		2	0	0	0	0	0	$6,573	

26	157.2	1				high			2	0	0	0	0	0		$6,573	
27	157.3	1				high			2	0	0	0	0	0		$5,585	
28	157.4	1				high			2	0	0	0	0	0		$5,585	
29	157.5	1				high			2	0	0	0	0	0		$18,129	
30	157.6	1				high			2	0	0	0	0	0		$14,349	
31	157.7	1				high			2	0	0	0	0	0		$13,145	
32	157.8	1				high			2	0	0	0	0	0		$13,747	
33	157.9	1				high			2	0	0	0	0	0		$13,747	
34	158.0	1				moderate			2	0	0	0	0	0		$15,552	
35	158.1	1				moderate			2	0	0	0	0	0		$15,552	
36	158.2	1				moderate			2	0	0	0	0	0		$16,153	
37	158.3	1				moderate			2	0	0	0	0	0		$18,344	
38	158.4	1				moderate			2	1	1	0	0	0		$17,743	
39	158.5	1				moderate			2	1	1	0	0	0		$30,115	1
40	158.6	1				moderate			2	1	1	0	0	0		$21,571	
41	158.7	1				moderate			2	1	1	0	0	0		$23,160	
42	158.8	1				moderate			2	1	1	0	0	0		$25,351	
43	158.9	1				moderate			2	1	1	0	0	0		$24,750	
44	159.0	1				high			2	1	1	0	1	0		$27,928	
45	159.1	1				high			2	1	1	0	1	0		$26,124	
46	159.2	1				high			2	1	1	0	1	0		$28,315	
47	159.3	1				high			2	1	1	0	1	0		$29,904	1
48	159.4	1				high			2	1	1	0	1	0		$28,916	
49	159.5	1				high			2	1	1	0	1	0		$43,480	2
50	159.6	1				high			2	1	1	0	1	0		$32,310	1
51	159.7	1				high			2	1	1	0	1	0		$28,311	
52	159.8	1				high			2	1	1	0	1	0		$26,721	
53	159.9	1				high			2	1	1	0	1	0		$24,531	
54	160.0	1				high			2	1	1	0	1	0		$26,721	
55	160.1	1				high			2	1	1	0	1	0		$23,543	
56	160.2	1				high			2	1	1	0	1	0		$26,721	
57	160.3	1				high			2	1	1	0	1	0		$25,132	
58	160.4	1				high			3	1	1	0	1	0		$22,941	
59	160.5	1				high			3	1	1	0	1	0		$34,884	1
60	160.6	1				high			2	1	1	0	1	0		$21,523	
61	160.7	1				high			2	1	1	0	1	0		$22,124	
62	160.8	1				high			2	1	1	0	1	0		$22,124	
0	160.9	1				high			2	1	1	0	1	0		$25,905	
63	161.0	1				very high			2	1	1	0	1	0		$26,506	
64	161.1	1				very high			2	1	1	0	0	0		$27,108	
65	161.2	1				very high			2	1	1	0	0	0		$29,299	1

66	161.3	1				very high			2	1	1	0	0	0		$26,721	
67	161.4	1				very high			2	1	1	0	0	0		$52,028	3
68	161.5	1				very high			2	1	1	0	0	0		$53,618	3
69	161.6	1				very high			2	1	1	0	0	0		$42,663	2
70	161.7	1				very high			2	1	1	0	0	0		$42,062	2
71	161.8	1				very high			2	1	1	0	0	0		$42,448	2
72	161.9	1				very high			2	1	1	0	0	0		$50,829	3
73	162.0	1							2	1	1	0	0	0		$47,049	3
74	162.1	1							2	1	1	0	0	0		$46,447	3
75	162.2	1							2	1	1	0	0	0		$44,858	2
76	162.3	1							2	1	1	0	0	0		$45,846	3
77	162.4	1							2	1	1	0	0	0		$52,419	3
78	162.5	1							2	1	1	0	0	0		$27,112	
79	162.6	1							2	1	1	0	0	0		$26,124	
80	162.7	1							2	1	1	0	0	0		$23,933	
81	162.8	1							2	1	1	0	0	0		$23,331	
82	162.9	1							2	1	1	0	0	0		$21,742	
83	163.0	1							2	1	1	0	0	0		$13,361	
84	163.1	1							2	1	1	0	0	0		$14,564	
85	163.2	1							2	1	1	0	0	0		$16,020	
86	163.3	1							2	1	1	0	0	0		$16,330	
87	163.4	1							2	1	1	0	0	0		$14,000	
88	163.5	1							2	1	1	0	0	0		$4,726	
89	163.6	1							2	1	1	0	0	0		$4,411	
1	132.6	2			moderate	moderate			1	0	0	0	0	0		$17,401	
2	132.7	2			moderate	moderate			1	0	0	0	0	0		$18,604	
3	132.8	2			moderate	moderate			1	0	0	0	0	0		$21,782	
4	132.9	2			moderate	moderate			1	0	0	0	0	0		$22,985	
5	133.0	2			moderate	moderate			1	0	0	0	0	0		$22,985	
6	133.1	2			moderate	moderate			1	0	0	0	0	0		$22,985	
7	133.2	2			moderate	moderate			1	0	0	0	0	0		$22,985	
8	133.3	2			moderate	moderate			1	0	0	0	0	0		$39,143	2
9	133.4	2			moderate	moderate			1	0	0	0	0	0		$28,144	
10	133.5	2			moderate	moderate			1	0	0	0	0	0		$27,928	
11	133.6	2			moderate				1	0	0	0	0	0		$27,928	
12	133.7	2			moderate				1	0	0	0	0	0		$28,530	
13	133.8	2			moderate				1	0	0	0	0	0		$27,928	
14	133.9	2			moderate				1	0	0	0	0	0		$25,351	
15	134.0	2			moderate				1	1	0	0	0	0		$24,148	
16	134.1	2			moderate				1	1	0	0	0	0		$24,750	
17	134.2	2			moderate				1	1	0	0	0	0		$24,750	

18	134.3	2			moderate				1	1	0	0	0	0		$34,501	1
19	134.4	2			moderate				1	1	0	0	0	0		$19,547	
20	134.5	2				moderate			1	1	0	0	0	0		$15,552	
21	134.6	2				moderate			1	1	0	0	0	0		$13,361	
22	134.7	2				moderate			1	1	0	0	0	0		$13,361	
23	134.8	2				moderate			1	1	0	0	0	0		$13,361	
24	134.9	2				moderate			1	1	0	0	0	0		$12,759	
25	135.0	2				moderate			1	1	0	0	0	0		$12,158	
26	135.1	2				moderate			1	1	0	0	0	0		$13,747	
27	135.2	2				moderate			1	1	0	0	0	0		$13,145	
28	135.3	2				moderate			1	1	0	0	0	0		$13,145	
29	135.4	2				moderate			1	1	0	0	0	0		$16,368	
30	135.5	2				moderate	moderate		1	1	0	0	0	0		$17,962	
31	135.6	2				moderate	moderate		1	1	0	0	0	0		$17,962	
32	135.7	2				moderate	moderate		1	1	0	0	0	0		$20,758	
33	135.8	2				moderate	moderate		1	1	0	0	0	0		$20,758	
34	135.9	2				moderate	moderate		1	1	0	0	0	0		$26,733	
35	136.0	2				moderate	moderate		1	1	1	0	0	0		$26,733	
36	136.1	2				moderate	moderate		1	1	1	0	0	0		$30,131	1
37	136.2	2				moderate	moderate		1	1	1	0	0	0		$31,720	1
38	136.3	2				moderate	moderate		1	1	1	0	0	0		$32,322	1
39	136.4	2				moderate	moderate		1	1	1	0	0	0		$49,463	3
40	136.5	2			moderate	moderate			1	1	1	0	0	0		$38,078	1
41	136.6	2			moderate	moderate			1	1	1	0	0	0		$35,883	1
42	136.7	2			moderate	moderate			1	1	1	0	0	0		$37,472	1
43	136.8	2			moderate	moderate			1	1	1	0	0	0		$34,676	1
44	136.9	2			moderate	moderate			1	1	1	0	0	0		$36,265	1
45	137.0	2			moderate	moderate			1	1	1	0	0	0		$31,278	1
46	137.1	2			moderate	moderate			1	1	1	0	0	0		$31,880	1
47	137.2	2			moderate	moderate			1	1	1	0	0	0		$28,482	
48	137.3	2			moderate	moderate			1	1	1	0	0	0		$25,303	
49	137.4	2			moderate	moderate			1	1	1	0	0	0		$49,061	3
50	137.5	2			moderate	moderate			2	1	1	0	0	0		$37,505	1
51	137.6	2			high	moderate			2	1	1	0	0	0		$41,118	2
52	137.7	2			high	moderate			2	1	1	0	0	0		$41,118	2
53	137.8	2			high	moderate			2	1	1	0	0	0		$41,118	2
54	137.9	2		moderate	high	moderate			2	1	1	0	0	0		$41,720	2
55	138.0	2		moderate	high	moderate			2	1	1	0	0	0		$40,130	2
56	138.1	2			high	moderate			1	0	0	0	0	0		$38,541	1
57	138.2	2			high	moderate			1	0	0	0	0	0		$39,529	2
58	138.3	2			high	moderate			1	0	0	0	0	0		$39,529	2

59	138.4	2			high	moderate			1	0	0	0	0	0		$57,145	3
60	138.5	2			high	moderate			1	0	0	0	0	0		$33,387	1
61	138.6	2			high				1	0	0	0	0	0		$28,403	
62	138.7	2			high				1	0	0	0	0	0		$23,201	
63	138.8	2			high				1	0	0	0	0	0		$22,599	
64	138.9	2			high				1	0	0	0	0	0		$27,412	
65	139.0	2			high				1	0	0	0	0	0		$26,810	
66	139.1	2			high				1	0	0	0	0	0		$27,412	
67	139.2	2			high				1	0	0	0	0	0		$29,818	1
68	139.3	2			high				1	0	0	0	0	0		$28,830	
69	139.4	2			high				1	0	0	0	0	0		$46,446	3
70	139.5	2			high				1	0	0	0	0	0		$29,431	1
71	139.6	2			moderate				1	0	0	0	0	0		$29,431	1
72	139.7	2			moderate				1	0	0	0	0	0		$29,431	1
73	139.8	2			moderate				1	0	0	0	0	0		$29,431	1
74	139.9	2			moderate				1	0	0	0	0	0		$34,630	1
75	140.0	2		moderate	moderate				1	0	1	0	0	0		$29,431	1
76	140.1	2			moderate				1	0	1	0	0	0		$31,236	1
77	140.2	2			moderate				1	0	1	0	0	0		$30,635	1
78	140.3	2			moderate				1	0	1	0	0	0		$28,830	
79	140.4	2			moderate				1	0	1	0	0	0		$28,228	
80	140.5	2			moderate				1	0	1	0	0	0		$19,420	
81	140.6	2			moderate				1	0	1	0	0	0		$18,819	
82	140.7	2			moderate				1	0	1	0	0	0		$18,819	
83	140.8	2			moderate				1	0	1	0	0	0		$19,420	
84	140.9	2			moderate				2	0	1	0	0	0		$20,022	
85	141.0	2			moderate				2	0	1	0	0	0		$17,014	
86	141.1	2			moderate				2	0	1	0	0	0		$16,413	
3	141.2	3			moderate				2	1	0	0	0	0		$15,811	
4	141.3	3			moderate				2	1	0	0	0	0		$17,014	
5	141.4	3			moderate				2	1	0	0	0	0		$19,420	
6	141.5	3			moderate				2	1	0	0	0	0		$40,259	2
7	141.6	3			moderate				2	1	0	0	0	0		$32,654	1
8	141.7	3			moderate				2	1	0	0	0	0		$33,256	1
9	141.8	3			moderate				2	1	0	0	0	0		$34,459	1
10	141.9	3		moderate	moderate				2	1	0	0	0	0		$34,459	1
11	142.0	3		moderate	moderate				2	1	0	0	0	0		$43,267	2
12	142.1	3		moderate	moderate				2	1	0	0	0	0		$42,279	2
13	142.2	3			moderate				2	1	0	0	0	0		$45,072	2
14	142.3	3			moderate				2	1	0	0	0	0		$44,470	2
15	142.4	3			moderate				2	1	0	0	0	0		$46,059	3

16	142.5	3			very high	moderate			2	1	0	0	0	0		$61,871	4
17	142.6	3			very high	moderate			1	1	0	0	0	0		$42,836	2
18	142.7	3			very high	moderate			1	1	0	0	0	0		$44,040	2
19	142.8	3			very high	moderate			1	1	0	0	0	0		$46,446	3
20	142.9	3			very high	moderate			1	1	0	0	0	0		$45,243	2
21	143.0	3		moderate	very high	moderate			1	1	0	0	0	0		$47,649	3
22	143.1	3			very high	moderate			1	1	0	0	0	0		$38,841	1
23	143.2	3			very high	moderate			2	1	0	0	0	0		$37,638	1
24	143.3	3			very high	moderate			2	1	0	0	0	0		$37,252	1
25	143.4	3			very high	moderate			2	1	0	0	0	0		$37,853	1
26	143.5	3			very high	moderate			2	1	0	0	0	0		$47,270	3
27	143.6	3			moderate				2	0	0	0	0	0		$30,041	1
28	143.7	3			moderate				2	0	0	0	0	0		$29,439	1
29	143.8	3			moderate				1	0	0	0	0	0		$27,033	
30	143.9	3			moderate				1	0	0	0	0	0		$24,025	
31	144.0	3			moderate				1	0	0	0	0	0		$26,216	
32	144.1	3			moderate				1	0	0	0	0	0		$22,607	
33	144.2	3			moderate				1	0	0	0	0	0		$22,607	
34	144.3	3			moderate				1	0	0	0	0	0		$24,196	
35	144.4	3			moderate				2	0	0	0	0	0		$22,778	
36	144.5	3			moderate				2	0	0	0	0	0		$28,793	
37	144.6	3				moderate			2	0	0	0	0	0		$16,584	
38	144.7	3				moderate			2	0	0	0	0	0		$15,596	
39	144.8	3				moderate			2	0	0	0	0	0		$14,393	
40	144.9	3				moderate			2	0	0	0	0	0		$15,982	
41	145.0	3				moderate			1	0	0	0	0	0		$17,787	
42	145.1	3				moderate			1	0	0	0	0	0		$14,994	
43	145.2	3				moderate			1	0	0	0	0	0		$14,994	
44	145.3	3				moderate			1	0	0	0	0	0		$14,994	
45	145.4	3				moderate			1	0	0	0	0	0		$14,007	
46	145.5	3				moderate			1	0	0	0	0	0		$42,458	2
47	145.6	3			high	very high			1	1	0	0	0	0		$39,235	2
48	145.7	3			high	very high			1	1	0	0	0	0		$45,421	3
49	145.8	3			high	very high			1	1	0	0	0	0		$48,819	3
50	145.9	3		moderate	high	very high			1	1	0	0	0	0		$49,421	3
51	146.0	3		moderate	high	very high			2	1	0	0	0	0		$60,806	4
52	146.1	3		moderate	high	very high			2	1	1	0	0	0		$62,782	4
53	146.2	3			high	very high			2	1	1	0	0	0		$65,574	4
54	146.3	3			high	very high			2	1	1	0	0	0		$72,362	4
55	146.4	3		moderate	high	very high			2	1	1	0	0	0		$75,155	4
56	146.5	3		moderate	high	very high			2	1	1	0	0	0		$112,277	4

57	146.6	3			high	moderate			2	1	1	0	0	0		$89,797	4
58	146.7	3			high	moderate			2	1	1	0	0	0		$93,577	4
59	146.8	3			high	moderate			2	1	1	0	0	0		$88,980	4
60	146.9	3		moderate	high	moderate			2	1	1	0	0	0		$87,172	4
61	147.0	3		high	high	moderate			2	1	1	0	0	0		$93,573	4
62	147.1	3		moderate	high	moderate			2	1	1	0	0	0		$84,208	4
63	147.2	3			high	moderate			2	1	1	0	0	0		$85,411	4
64	147.3	3			high	moderate			2	1	1	0	0	0		$85,411	4
65	147.4	3			high	moderate			2	1	1	0	0	0		$80,814	4
66	147.5	3			moderate				2	1	1	0	0	0		$100,580	4
67	147.6	3			moderate				2	0	1	0	0	0		$62,856	4
68	147.7	3			moderate				2	0	1	0	0	0		$57,100	3
69	147.8	3			moderate				2	0	1	0	0	0		$49,926	3
70	147.9	3			moderate				2	0	1	0	0	0		$48,337	3
71	148.0	3			moderate				2	0	1	0	0	0		$46,747	3
72	148.1	3			moderate				2	0	1	0	0	0		$41,333	2
73	148.2	3			moderate				2	0	1	0	0	0		$38,326	1
74	148.3	3			moderate				2	0	1	0	0	0		$33,944	1
75	148.4	3			moderate				2	0	1	0	0	0		$31,151	1
76	148.5	3			moderate				2	0	1	0	0	0		$44,991	2
77	148.6	3			moderate				2	0	1	0	0	0		$22,432	
78	148.7	3			moderate				2	0	1	0	0	0		$25,830	
79	148.8	3			moderate				2	0	0	0	0	0		$25,228	
80	148.9	3			moderate				2	0	0	0	0	0		$24,627	
81	149.0	3			moderate				2	0	0	0	0	0		$27,635	
82	149.1	3			moderate				1	0	0	0	0	0		$27,033	
83	149.2	3			moderate				1	0	0	0	0	0		$30,041	1
84	149.3	3			moderate				1	0	0	0	0	0		$31,845	1
85	149.4	3			moderate				1	0	0	0	0	0		$36,056	1
86	149.5	3			very high		moderate		1	0	0	0	0	0		$72,889	4
87	149.6	3			very high		moderate		1	1	0	0	0	0		$59,050	3
88	149.7	3			very high		moderate		1	1	0	0	0	0		$64,252	4
89	149.8	3		moderate	very high		moderate		1	1	0	0	0	0		$62,057	4
90	149.9	3		high	very high		moderate		1	1	0	0	0	0		$65,065	4
91	150.0	3		high	very high		moderate		1	1	0	0	0	0		$70,865	4
92	150.1	3		moderate	very high		moderate		1	1	0	0	0	0		$70,650	4
93	150.2	3			very high		moderate		2	1	0	0	0	0		$71,853	4
94	150.3	3			very high		moderate		2	1	0	0	0	0		$72,455	4
95	150.4	3			very high		moderate		2	1	0	0	0	0		$72,455	4
96	150.5	3			very high				2	1	0	0	0	0		$89,855	4
97	150.6	3			very high	high			2	1	0	0	0	0		$54,225	3

98	150.7	3			very high	high			2	1	0	0	0	0		$57,835	3
99	150.8	3			very high	high			2	1	0	0	0	0		$55,811	3
100	150.9	3		moderate	very high	high			2	1	0	0	0	0		$55,209	3
101	151.0	3		moderate	very high	high			2	1	0	0	0	0		$76,736	4
102	151.1	3		moderate	very high	high			2	1	0	0	0	0		$75,533	4
103	151.2	3			very high	high			2	1	0	0	0	0		$80,134	4
104	151.3	3			very high	high			2	1	0	0	0	0		$85,723	4
105	151.4	3		moderate	very high	high			2	1	0	0	0	0		$83,532	4
106	151.5	3		moderate	very high	high	moderate		2	1	0	0	0	0		$103,135	4
107	151.6	3		moderate	high		moderate		2	1	0	0	0	0		$83,328	4
108	151.7	3		moderate	high		moderate		2	1	0	0	0	0		$89,132	4
109	151.8	3			high		moderate		2	1	0	0	0	0		$87,933	4
110	151.9	3		moderate	high		moderate		2	1	0	0	0	0		$88,364	4
111	152.0	3		moderate	high		moderate		2	1	0	0	0	0		$95,582	4
112	152.1	3			high		moderate		2	1	0	0	0	0		$71,048	4
113	152.2	3			high		moderate		2	1	0	0	0	0		$67,052	4
114	152.3	3			high		moderate		2	1	0	0	0	0		$71,056	4
115	152.4	3			high		moderate		2	1	0	0	0	0		$67,873	4
116	152.5	3			high				2	1	0	0	0	0		$93,528	4
117	152.6	3			high				2	1	0	0	0	0		$74,527	4
118	152.7	3			high				2	1	0	0	0	0		$74,527	4
119	152.8	3		moderate	high				2	1	0	0	0	0		$69,324	4
120	152.9	3		high	high				2	1	0	0	0	0		$69,535	4
121	153.0	3		very high	high				2	1	0	0	0	0		$80,965	4
2	153.1	4		high	high				2	1	0	0	0	0		$87,370	4
3	153.2	4			high				2	1	0	0	0	0		$95,190	4
4	153.3	4			high				2	1	0	0	0	0		$100,604	4
5	153.4	4		moderate	high				2	1	0	0	0	0		$98,832	4
6	153.5	4		high	high		moderate		2	1	0	0	0	0		$113,660	4
7	153.6	4		very high	moderate		moderate		2	1	0	0	0	0		$86,200	4
8	153.7	4		high	moderate		moderate		2	1	0	0	0	0		$83,192	4
9	153.8	4		high	moderate		moderate		2	1	0	0	0	0		$80,786	4
10	153.9	4		high	moderate		moderate		2	1	0	0	0	0		$78,981	4
11	154.0	4		moderate	moderate		moderate		2	1	0	0	0	0		$74,169	4
12	154.1	4			moderate		moderate		2	1	0	0	0	0		$59,130	3
13	154.2	4			moderate		moderate		2	1	0	0	0	0		$44,905	2
14	154.3	4			moderate		moderate		2	1	0	0	0	0		$37,686	1
15	154.4	4			moderate		moderate		1	1	0	0	0	0		$32,272	1
16	154.5	4			moderate				2	1	0	0	0	0		$37,650	1
17	154.6	4			moderate				2	1	0	0	0	0		$20,416	
18	154.7	4			moderate				2	1	0	0	0	0		$24,025	

19	154.8	4			moderate				2	1	0	0	0	0		$26,216	
20	154.9	4			moderate				2	1	0	0	0	0		$26,216	
21	155.0	4			moderate				2	1	1	0	0	0		$28,021	
22	155.1	4			moderate				2	1	1	0	0	0		$29,826	1
23	155.2	4			moderate				2	1	1	0	0	0		$29,826	1
24	155.3	4			moderate				2	1	1	0	0	0		$30,427	1
25	155.4	4			moderate				2	1	1	0	0	0		$28,622	
26	155.5	4			moderate				2	1	1	0	0	0		$41,812	2
27	155.6	4			moderate	high			2	1	1	0	0	0		$26,810	
28	155.7	4			moderate	high			2	1	1	0	0	0		$27,412	
29	155.8	4			moderate	high			2	0	1	0	0	0		$26,379	
30	155.9	4			moderate	high			2	0	1	0	0	0		$24,189	
31	156.0	4			moderate	high			2	0	1	0	0	0		$29,172	1
32	156.1	4			moderate	high			2	0	1	0	0	0		$27,367	
33	156.2	4			moderate	high			2	0	1	0	0	0		$26,164	
34	156.3	4			moderate	high			2	0	1	0	0	0		$27,152	
35	156.4	4			moderate	high			2	0	1	0	0	0		$27,754	
36	156.5	4			moderate	high	moderate		2	0	1	0	0	0		$51,296	3
37	156.6	4				high	moderate		2	0	1	0	0	0		$38,107	1
38	156.7	4				high	moderate		2	0	1	0	0	0		$38,107	1
39	156.8	4				high	moderate		2	0	1	0	0	0		$37,891	1
40	156.9	4				high	moderate		2	0	1	0	0	0		$40,688	2
41	157.0	4				high	moderate		2	0	1	0	0	0		$52,630	3
42	157.1	4				high	moderate		2	0	1	0	0	0		$52,028	3
43	157.2	4				high	moderate		2	0	1	0	0	0		$55,809	3
44	157.3	4				high	moderate		2	0	1	0	0	0		$61,182	4
45	157.4	4				high	moderate		2	0	1	0	0	0		$61,784	4
46	157.5	4				high			2	0	1	0	0	0		$82,969	4
47	157.6	4			moderate	moderate			2	0	1	0	0	0		$64,023	4
48	157.7	4			moderate	moderate			2	0	1	0	0	0		$71,807	4
49	157.8	4			moderate	moderate			2	0	1	0	0	0		$73,611	4
50	157.9	4		moderate	moderate	moderate			2	0	1	0	0	0		$72,623	4
51	158.0	4		moderate	moderate	moderate			2	0	1	0	0	0		$70,644	4
52	158.1	4		moderate	moderate	moderate			2	0	1	0	0	0		$60,892	4
53	158.2	4			moderate	moderate			2	0	1	0	0	0		$57,112	3
54	158.3	4			moderate	moderate			2	0	1	0	0	0		$53,933	3
55	158.4	4			moderate	moderate			2	0	1	0	0	0		$47,958	3
56	158.5	4			moderate	moderate			2	0	1	0	0	0		$45,767	3
57	158.6	4							2	0	1	0	0	0		$23,380	
58	158.7	4							2	0	1	0	0	0		$19,384	
59	158.8	4							2	0	1	0	0	0		$10,999	

60	158.9	4							2	0	1	0	0	0		$9,194	
61	159.0	4							2	0	1	0	0	0		$8,593	
62	159.1	4							2	0	1	0	0	0		$4,597	
63	159.2	4							2	0	1	0	0	0		$2,406	
64	159.3	4							2	0	1	0	0	0		$1,805	
65	159.4	4							2	0	1	0	0	0		$1,203	
66	159.5	4							2	0	1	0	0	0		$1,203	
67	159.6	4							2	0	1	0	0	0		$1,203	
68	159.7	4							2	0	1	0	0	0		$1,805	
69	159.8	4							2	0	1	0	0	0		$1,203	
70	159.9	4							2	0	1	0	0	0		$1,203	
71	160.0	4							2	0	1	0	0	0		$1,203	
72	160.1	4							2	0	1	0	0	0		$1,203	
73	160.2	4							2	0	1	0	0	0		$8,385	
74	160.3	4							2	0	1	0	0	0		$8,987	
75	160.4	4							2	0	1	0	0	0		$9,885	
76	160.5	4							2	0	1	0	0	0		$10,984	
77	160.6	4							2	0	1	0	0	0		$12,357	
78	160.7	4							2	0	1	0	0	0		$14,122	
79	160.8	4							2	0	1	0	0	0		$15,373	
1	2.0	5							1	0	1	0	0	0		$6,931	
2	2.1	5							1	0	1	0	0	0		$5,940	
3	2.2	5							1	0	1	0	0	0		$5,198	
4	2.3	5							1	0	1	0	0	0		$5,356	
5	2.4	5							1	0	1	0	0	0		$4,820	
6	2.5	5							1	0	1	0	0	0		$4,382	
7	2.6	5							1	0	1	1	0	0		$4,382	
8	2.7	5							1	0	1	1	0	0		$5,971	
9	2.8	5							1	0	1	1	0	0		$5,971	
10	2.9	5							1	0	1	1	0	0		$4,382	
11	3.0	5							1	0	1	0	0	0		$3,780	
12	3.1	5							1	0	1	0	0	0		$2,191	
13	3.2	5							1	0	1	1	0	0		$2,191	
14	3.3	5							1	0	1	1	0	0		$2,191	
15	3.4	5							1	0	1	1	0	0		$1,589	
16	3.5	5							1	0	1	1	0	0		$1,589	
17	3.6	5							1	0	1	1	0	0		$1,589	
18	3.7	5							1	0	1	1	0	0		$1,589	
19	3.8	5							1	0	1	1	0	0		$0	
20	3.9	5							1	0	1	1	0	0		$0	
21	4.0	5							1	0	1	1	0	0		$0	

22	4.1	5							1	0	1	1	0	0		$0	
23	4.2	5							1	0	1	1	0	0		$0	
24	4.3	5							1	0	1	1	0	0		$0	
25	4.4	5							1	0	1	0	0	0		$0	
26	4.5	5							1	0	1	0	0	0		$3,780	
94	4.6	5							1	0	1	0	0	0		$3,780	
95	4.7	5							1	0	1	0	0	0		$3,780	
96	4.8	5							1	0	1	0	0	0		$3,780	
97	4.9	5							1	0	1	0	0	0		$3,780	
98	5.0	5							1	0	1	0	0	0		$3,780	
99	5.1	5							1	0	1	0	0	0		$3,780	
100	5.2	5							1	0	1	0	0	0		$3,780	
101	5.3	5							1	0	1	0	0	0		$3,780	
102	5.4	5							1	0	1	0	0	0		$3,780	
103	5.5	5							1	0	1	0	0	0		$5,370	
104	5.6	5							1	0	1	0	0	0		$1,589	
105	5.7	5							1	0	1	0	0	0		$1,589	
106	5.8	5							1	0	1	0	0	0		$1,589	
107	5.9	5							1	0	1	0	0	0		$1,589	
108	6.0	5							1	0	1	1	0	0		$1,589	
109	6.1	5							1	0	1	1	0	0		$1,589	
110	6.2	5							1	0	1	1	0	0		$3,179	
111	6.3	5							1	0	1	1	0	0		$6,357	
112	6.4	5							1	0	1	1	0	0		$6,357	
113	6.5	5							1	0	1	0	0	0		$9,150	
114	6.6	5							1	0	1	0	0	0		$10,357	
115	6.7	5							1	0	1	0	0	0		$10,357	
116	6.8	5							1	0	1	0	0	0		$10,357	
117	6.9	5							2	0	1	0	0	0		$11,946	
118	7.0	5							2	0	1	1	0	0		$15,125	
119	7.1	5							2	0	1	1	0	0		$15,125	
120	7.2	5							2	0	1	1	0	0		$15,727	
121	7.3	5							2	0	1	1	0	0		$14,137	
122	7.4	5							2	0	1	1	0	0		$10,958	
123	7.5	5							2	0	1	1	0	0		$10,958	
124	7.6	5							2	0	1	1	0	0		$8,166	
125	7.7	5							2	0	1	1	0	0		$5,971	
126	7.8	5							2	0	1	1	0	0		$5,971	
127	7.9	5							2	0	1	1	0	0		$7,561	
128	8.0	5							2	0	1	1	0	1		$7,174	
129	8.1	5							1	0	1	1	0	1		$3,996	

130	8.2	5							1	0	1	1	0	1		$4,597	
131	8.3	5							1	0	1	1	0	1		$3,996	
132	8.4	5							1	0	1	1	0	1		$3,996	
133	8.5	5							1	0	1	1	0	1		$5,199	
134	8.6	5							1	0	1	1	0	1		$5,199	
135	8.7	5							1	0	1	1	0	1		$5,199	
136	8.8	5							1	0	1	1	0	1		$4,597	
137	8.9	5							1	0	0	1	0	1		$4,597	
138	9.0	5							1	0	0	1	0	1		$3,008	
139	9.1	5							1	0	0	1	0	1		$1,805	
140	9.2	5							1	0	0	1	0	1		$1,805	
141	9.3	5							1	0	0	1	0	1		$1,805	
142	9.4	5							1	0	0	1	0	1		$1,805	
143	9.5	5							1	0	0	1	0	1		$6,788	
144	9.6	5							1	0	0	1	0	1		$5,585	
145	9.7	5							1	0	0	1	0	1		$5,585	
146	9.8	5							1	0	0	1	0	1		$5,585	
147	9.9	5							1	0	0	0	0	1		$5,585	
148	10.0	5							1	0	0	0	0	1		$6,186	
149	10.1	5							1	0	0	0	0	1		$6,186	
150	10.2	5							1	0	0	0	0	1		$6,186	
151	10.3	5							1	0	0	0	0	1		$6,186	
152	10.4	5							1	0	0	0	0	1		$5,585	
153	10.5	5							1	0	0	0	0	1		$5,585	
154	10.6	5							1	0	0	0	0	1		$602	
155	10.7	5							1	0	0	0	0	1		$602	
156	10.8	5							1	0	0	0	0	1		$602	
157	10.9	5							1	0	0	0	0	1		$2,191	
158	11.0	5							1	0	0	0	0	1		$3,780	
159	11.1	5							1	0	0	0	0	1		$3,179	
160	11.2	5							1	0	0	0	0	1		$3,179	
161	11.3	5							1	0	0	0	0	1		$3,179	
162	11.4	5							2	0	0	0	0	1		$3,179	
163	11.5	5							2	0	0	0	0	1		$6,577	
164	11.6	5							2	0	0	0	0	1		$6,577	
165	11.7	5							2	0	0	0	0	1		$6,577	
166	11.8	5							2	0	0	0	0	1		$6,577	
167	11.9	5							2	0	0	0	0	1		$6,577	
168	12.0	5							1	0	0	0	0	1		$4,987	
169	12.1	5							1	0	0	0	0	1		$3,398	
170	12.2	5							1	0	0	0	0	1		$3,398	

171	12.3	5							1	0	0	0	0	1		$3,398	
172	12.4	5							1	0	0	0	0	1		$3,398	
173	12.5	5							1	0	0	0	0	1		$3,398	
174	12.6	5							1	0	0	0	0	1		$0	
175	12.7	5							1	0	0	0	0	1		$0	
176	12.8	5							1	0	0	0	0	1		$0	
177	12.9	5							1	0	0	0	0	1		$0	
178	13.0	5							1	0	0	0	0	1		$602	
179	13.1	5							1	0	0	0	0	1		$602	
180	13.2	5							1	0	0	0	0	1		$602	
181	13.3	5							2	0	0	0	0	1		$602	
182	13.4	5							2	0	0	0	0	1		$602	
183	13.5	5							2	0	0	0	0	1		$1,805	
184	13.6	5							2	0	0	0	0	1		$3,008	
185	13.7	5							2	0	0	0	0	1		$3,609	
186	13.8	5							2	0	0	0	0	1		$3,609	
187	13.9	5							2	0	0	0	0	1		$3,609	
188	14.0	5							2	0	0	0	0	1		$3,609	
189	14.1	5							2	0	0	0	0	1		$3,609	
190	14.2	5							2	0	0	0	0	1		$3,609	
191	14.3	5							2	0	0	0	0	1		$3,609	
192	14.4	5							2	0	0	0	0	1		$3,609	
193	14.5	5							2	0	0	0	0	1		$3,609	
194	14.6	5							2	0	0	0	0	1		$3,008	
195	14.7	5							1	0	0	0	0	1		$1,805	
196	14.8	5							1	0	0	0	0	1		$1,203	
197	14.9	5							1	0	0	0	0	1		$1,203	
198	15.0	5							1	0	0	0	0	1		$1,203	
199	15.1	5							2	0	0	0	0	1		$1,203	
200	15.2	5							2	0	0	0	0	1		$602	
201	15.3	5							2	0	0	0	0	1		$602	
202	15.4	5							2	0	0	0	0	1		$602	
203	15.5	5							2	0	0	0	0	1		$602	
204	15.6	5							2	0	0	0	0	1		$1,805	
205	15.7	5							1	0	0	0	0	1		$1,805	
206	15.8	5							2	0	0	0	0	1		$1,805	
207	15.9	5							2	0	0	0	0	1		$1,805	
208	16.0	5							2	0	0	0	0	1		$1,805	
209	16.1	5							2	0	0	0	0	1		$1,805	
210	16.2	5							2	0	0	0	0	1		$2,406	
211	16.3	5							2	0	0	0	0	1		$3,008	

212	16.4	5							1	0	0	0	0	1		$3,008	
213	16.5	5							1	0	0	0	0	1		$3,008	
214	16.6	5							1	0	0	0	0	1		$3,609	
215	16.7	5							1	0	0	0	0	1		$2,406	
216	16.8	5							1	0	0	0	0	1		$1,805	
217	16.9	5							1	0	0	0	0	1		$1,805	
218	17.0	5							1	0	0	0	0	1		$2,406	
219	17.1	5							1	0	0	0	0	1		$2,406	
220	17.2	5							1	0	0	0	0	1		$2,406	
221	17.3	5							1	0	0	0	0	1		$1,805	
1	17.4	5							1	0	0	0	0	1		$1,805	
2	17.5	5							1	0	0	0	0	1		$1,805	
3	17.6	5							1	0	0	0	0	1		$3,996	
4	17.7	5							1	0	0	0	0	1		$3,996	
5	17.8	5							1	0	0	0	0	1		$3,996	
6	17.9	5							1	0	0	0	0	1		$3,996	
7	18.0	5							1	0	0	0	0	1		$3,996	
8	18.1	5							1	0	0	0	0	1		$4,597	
9	18.2	5							1	0	0	0	0	1		$5,199	
10	18.3	5							1	0	0	0	0	1		$5,199	
11	18.4	5							1	0	0	0	0	1		$5,199	
12	18.5	5							1	0	0	0	0	1		$4,597	
13	18.6	5							1	0	0	0	0	1		$4,597	
14	18.7	5							1	0	0	0	0	1		$2,406	
15	18.8	5							1	0	0	0	0	1		$1,805	
16	18.9	5							1	0	0	0	0	1		$1,805	
17	19.0	5							1	0	0	0	0	1		$3,394	
18	19.1	5							1	0	0	0	0	1		$3,394	
19	19.2	5							1	0	0	0	0	1		$2,191	
20	19.3	5							1	0	0	0	0	1		$1,589	
21	19.4	5							1	0	0	0	0	1		$1,589	
22	19.5	5							1	0	0	0	0	1		$2,191	
23	19.6	5							1	0	0	0	0	1		$4,382	
24	19.7	5							1	0	0	0	0	1		$4,382	
25	19.8	5							1	0	0	0	0	1		$4,382	
26	19.9	5							1	0	0	0	0	1		$4,382	
27	20.0	5							1	0	0	0	0	1		$4,382	
28	20.1	5							1	0	0	0	0	1		$2,792	
29	20.2	5							1	0	0	0	0	1		$2,792	
30	20.3	5							1	0	0	0	0	1		$2,792	
31	20.4	5							1	0	0	0	0	1		$2,792	

32	20.5	5							1	0	0	0	0	1		$2,792	
33	20.6	5							1	0	0	0	0	1		$2,792	
34	20.7	5							1	0	0	0	0	1		$602	
35	20.8	5							1	0	0	0	0	1		$1,203	
36	20.9	5							1	0	0	0	0	1		$1,203	
37	21.0	5							1	0	0	0	0	1		$1,805	
38	21.1	5							1	0	0	0	0	1		$1,805	
39	21.2	5							1	0	0	0	0	1		$1,805	
40	21.3	5							1	0	0	0	0	1		$1,805	
41	21.4	5							1	0	0	0	0	1		$1,805	
42	21.5	5							1	0	0	0	0	1		$2,406	
43	21.6	5							1	0	0	0	0	1		$2,406	
44	21.7	5							1	0	0	0	0	1		$1,805	
45	21.8	5							1	0	0	0	0	1		$1,805	
46	21.9	5							1	0	0	0	0	1		$1,203	
47	22.0	5							1	0	0	0	0	1		$1,203	
48	22.1	5							1	0	0	0	0	1		$602	
49	22.2	5							1	0	0	0	0	1		$1,203	
50	22.3	5							1	0	0	0	0	1		$1,203	
51	22.4	5							1	0	0	0	0	1		$1,203	
52	22.5	5							1	0	0	0	0	1		$1,203	
53	22.6	5							1	0	0	0	0	1		$602	
54	22.7	5							1	0	0	0	0	1		$602	
55	22.8	5							1	0	0	0	0	1		$602	
56	22.9	5							1	0	0	0	0	1		$602	
57	23.0	5							1	0	0	0	0	1		$602	
58	23.1	5							1	0	0	0	0	1		$602	
59	23.2	5							1	0	0	0	0	1		$602	
60	23.3	5							1	0	0	0	0	1		$0	
61	23.4	5							1	0	0	0	0	1		$0	
62	23.5	5							1	0	0	0	0	1		$0	
63	23.6	5							1	0	0	0	0	1		$602	
64	23.7	5							1	0	0	0	0	1		$602	
65	23.8	5							1	0	0	0	0	1		$602	
66	23.9	5							1	0	0	0	0	1		$602	
67	24.0	5							1	0	0	0	0	1		$602	
68	24.1	5							1	0	0	0	0	1		$602	
69	24.2	5							1	0	0	0	0	1		$602	
70	24.3	5							1	0	0	0	0	1		$602	
71	24.4	5							1	0	0	0	0	1		$1,203	
72	24.5	5							1	0	0	0	0	1		$1,203	

73	24.6	5							1	0	0	0	0	1		$1,203	
74	24.7	5							1	0	0	0	0	1		$602	
75	24.8	5							1	0	0	0	0	1		$602	
76	24.9	5							1	0	0	0	0	1		$602	
77	25.0	5							1	0	0	0	0	1		$602	
78	25.1	5							1	0	0	0	0	1		$602	
79	25.2	5							1	0	0	0	0	1		$1,805	
80	25.3	5							1	0	0	0	0	1		$1,805	
81	25.4	5							1	0	0	0	0	1		$1,805	
82	25.5	5							1	0	0	0	0	1		$1,805	
83	25.6	5							1	0	0	0	0	1		$2,406	
84	25.7	5							1	0	0	0	0	1		$2,406	
85	25.8	5							1	0	0	0	0	1		$2,406	
86	25.9	5							1	0	0	0	0	1		$2,406	
87	26.0	5							1	0	0	0	0	1		$2,406	
88	26.1	5							1	0	0	0	0	1		$2,406	
89	26.2	5							1	0	0	0	0	1		$2,406	
90	26.3	5							1	0	0	0	0	1		$1,323	
91	26.4	5							1	0	0	0	0	1		$1,470	
92	26.5	5							1	0	0	0	0	1		$1,654	
93	26.6	5							1	0	0	0	0	1		$945	
0	26.7	5							1	0	0	0	0	1		$0	
141	0.0	6		very high	high				2	1	0	0	0	0		$36,312	1
142	0.1	6		high	high				2	1	0	0	0	0		$32,070	1
143	0.2	6			high				2	1	0	0	0	0		$33,259	1
144	0.3	6			high				2	1	0	0	0	0		$38,804	1
145	0.4	6			high				2	1	0	0	0	0		$36,247	1
146	0.5	6			high				2	1	0	0	0	0		$48,548	3
147	0.6	6			moderate	moderate	moderate		2	1	0	0	0	0		$58,300	3
148	0.7	6			moderate	moderate	moderate		2	1	0	0	0	0		$59,458	3
149	0.8	6			moderate	moderate	moderate		2	1	1	0	0	0		$61,434	4
150	0.9	6			moderate	moderate	moderate		2	1	1	0	0	0		$67,409	4
151	1.0	6		moderate	moderate	moderate	moderate		2	1	1	0	0	0		$73,380	4
152	1.1	6		moderate	moderate	moderate	moderate		2	1	1	0	0	0		$70,759	4
153	1.2	6		moderate	moderate	moderate	moderate		2	1	1	0	0	0		$82,928	4
154	1.3	6			moderate	moderate	moderate		2	1	1	0	0	0		$82,156	4
155	1.4	6			moderate	moderate	moderate		2	1	1	0	0	0		$81,554	4
156	1.5	6			moderate	moderate	moderate		2	1	1	0	0	0		$113,055	4
157	1.6	6				high	moderate		2	1	1	0	0	0		$104,255	4
158	1.7	6				high	moderate		2	1	1	0	0	0		$96,308	4
159	1.8	6		moderate		high	moderate		2	1	1	1	0	0		$94,118	4

160	1.9	6		moderate		high	moderate		2	1	1	1	0	0		$89,134	4
161	2.0	6		moderate		high	moderate		2	1	1	1	0	0		$84,147	4
162	2.1	6				high	moderate		2	1	1	1	0	0		$74,395	4
163	2.2	6				high	moderate		2	1	1	1	0	0		$70,014	4
164	2.3	6				high	moderate		2	1	1	1	0	0		$58,832	3
165	2.4	6				high	moderate		2	1	1	1	0	0		$56,426	3
166	2.5	6				high	moderate		2	1	0	0	0	0		$60,421	4
167	2.6	6				moderate			2	1	0	0	0	0		$27,717	
168	2.7	6				moderate			2	1	0	0	0	0		$23,714	
169	2.8	6				moderate			2	1	0	0	0	0		$22,511	
170	2.9	6				moderate			2	1	0	0	0	0		$19,933	
171	3.0	6				moderate			2	0	0	1	0	0		$27,116	
172	3.1	6				moderate			2	0	0	1	0	0		$28,924	
173	3.2	6				moderate			2	0	0	1	0	0		$32,924	1
174	3.3	6				moderate			2	0	1	1	0	0		$39,118	2
175	3.4	6				moderate			2	0	1	1	0	0		$39,333	2
176	3.5	6				moderate			2	0	1	1	0	0		$39,935	2
177	3.6	6					very high		2	0	1	1	0	0		$32,378	1
1	3.7	6					very high		2	0	0	1	0	0		$35,776	1
2	3.8	6					very high		3	0	0	1	0	0		$38,576	1
3	3.9	6					very high		4	0	0	1	0	0		$37,975	1
4	4.0	6					very high		5	0	0	1	0	0		$37,373	1
5	4.1	6					very high		6	0	0	1	0	0		$29,589	1
6	4.2	6					very high		5	0	0	1	0	0		$26,793	
7	4.3	6					very high		4	0	0	1	0	0		$22,794	
8	4.4	6					very high		3	0	0	1	0	0		$19,396	
9	4.5	6					very high		2	0	0	1	0	0		$25,371	
10	4.6	6							2	0	0	1	0	0		$24,769	
11	4.7	6							2	0	0	1	0	0		$24,168	
12	4.8	6							2	0	0	1	0	0		$20,770	
13	4.9	6							2	0	0	1	0	0		$15,177	
14	5.0	6							2	0	0	1	0	0		$15,177	
15	5.1	6							2	0	0	0	0	0		$14,576	
16	5.2	6							3	0	0	0	0	0		$14,576	
17	5.3	6							3	0	0	0	0	0		$13,974	
18	5.4	6							4	0	0	0	0	0		$13,974	
19	5.5	6							3	0	0	0	0	0		$16,982	
20	5.6	6							3	0	0	0	0	0		$9,804	
21	5.7	6							2	0	0	0	0	0		$11,998	
22	5.8	6							2	0	0	0	0	0		$14,189	
23	5.9	6							2	0	0	0	0	0		$14,189	

24	6.0	6							2	0	0	0	0	0		$17,583	
25	6.1	6							2	0	0	0	0	1		$18,185	
26	6.2	6							2	0	0	0	0	1		$24,379	
27	6.3	6							2	0	0	0	0	1		$24,981	
28	6.4	6							2	0	0	0	0	1		$25,582	
29	6.5	6							2	0	0	0	0	1		$27,988	
30	6.6	6							2	0	0	0	0	1		$22,786	
31	6.7	6							2	0	0	0	0	1		$22,786	
32	6.8	6							2	0	0	0	0	1		$20,591	
33	6.9	6							2	0	0	0	0	1		$15,604	
34	7.0	6							2	0	0	0	0	1		$16,807	
35	7.1	6							2	0	0	0	0	1		$14,014	
36	7.2	6							2	0	0	0	0	1		$13,413	
37	7.3	6							2	0	0	0	0	1		$7,219	
38	7.4	6							2	0	0	0	0	1		$7,219	
39	7.5	6							1	0	0	0	0	1		$10,397	
40	7.6	6							1	0	0	0	0	1		$7,991	
41	7.7	6							1	0	0	0	0	1		$8,979	
42	7.8	6							1	0	0	0	0	1		$8,377	
43	7.9	6							1	0	0	0	0	1		$8,377	
44	8.0	6							1	0	0	0	0	1		$10,568	
45	8.1	6							1	0	0	0	0	1		$9,365	
46	8.2	6							1	0	0	0	0	1		$12,162	
47	8.3	6							1	0	0	0	0	1		$12,162	
48	8.4	6							1	0	0	0	0	1		$12,162	
49	8.5	6					moderate		1	0	0	0	0	1		$17,145	
50	8.6	6					moderate		1	0	0	0	0	1		$18,957	
51	8.7	6					moderate		1	0	0	0	0	1		$18,957	
52	8.8	6					moderate		1	0	0	0	0	1		$17,368	
53	8.9	6					moderate		2	0	0	0	0	1		$17,368	
54	9.0	6					moderate		2	0	0	0	0	1		$17,970	
55	9.1	6					moderate		2	0	0	0	0	1		$15,779	
56	9.2	6					moderate		2	0	0	0	0	1		$15,779	
57	9.3	6					moderate		2	0	0	0	0	1		$12,381	
58	9.4	6					moderate		2	0	0	0	0	1		$12,381	
59	9.5	6							2	0	0	0	0	1		$15,775	
60	9.6	6							2	0	0	0	0	1		$10,190	
61	9.7	6							2	0	0	0	0	1		$4,597	
62	9.8	6							2	0	0	0	0	1		$4,597	
63	9.9	6							2	0	0	0	0	1		$4,597	
64	10.0	6							2	0	0	0	0	1		$6,186	

65	10.1	6							2	0	0	0	0	1		$4,983	
66	10.2	6							2	0	0	0	0	1		$4,983	
67	10.3	6							2	0	0	0	0	1		$6,186	
68	10.4	6							2	0	0	0	0	1		$6,186	
69	10.5	6							1	0	0	0	0	1		$6,788	
70	10.6	6							1	0	0	0	0	1		$3,394	
71	10.7	6							1	0	0	0	0	1		$3,394	
72	10.8	6							1	0	0	0	0	1		$3,394	
73	10.9	6							1	0	0	0	0	1		$3,394	
74	11.0	6							1	0	0	0	0	1		$5,199	
75	11.1	6							1	0	0	0	0	1		$3,609	
76	11.2	6							1	0	0	0	0	1		$3,609	
77	11.3	6							1	0	0	0	0	1		$4,211	
78	11.4	6							1	0	0	0	0	1		$3,008	
79	11.5	6							2	0	0	0	0	1		$12,811	
80	11.6	6							2	0	0	0	0	1		$12,210	
81	11.7	6							2	0	0	0	0	1		$12,210	
82	11.8	6							2	0	0	0	0	1		$12,210	
83	11.9	6							2	0	0	0	0	1		$12,210	
84	12.0	6							2	0	0	0	0	1		$12,210	
85	12.1	6							2	0	0	0	0	1		$10,405	
86	12.2	6							2	0	0	0	0	1		$10,405	
87	12.3	6							1	0	0	0	0	1		$10,405	
88	12.4	6							1	0	0	0	0	1		$9,804	
89	12.5	6							1	0	0	0	0	1		$16,209	
90	12.6	6							1	0	0	0	0	1		$6,406	
91	12.7	6							1	0	0	0	0	1		$6,406	
92	12.8	6							1	0	0	0	0	1		$6,406	
93	12.9	6							1	0	0	0	0	1		$6,406	
94	13.0	6							1	0	0	0	0	1		$9,202	
95	13.1	6							1	0	0	0	0	1		$17,197	
96	13.2	6							1	0	0	0	0	1		$18,400	
97	13.3	6							1	0	0	0	0	1		$25,797	
98	13.4	6							1	0	0	0	0	1		$27,602	
99	13.5	6					moderate		1	0	0	0	0	1		$33,406	1
100	13.6	6					moderate		2	0	0	0	0	1		$27,001	
101	13.7	6					moderate		2	0	0	0	0	1		$27,602	
102	13.8	6					moderate		2	0	0	0	0	1		$28,805	
103	13.9	6					moderate		2	0	0	0	0	1		$31,602	1
104	14.0	6					moderate		2	0	0	0	0	1		$32,805	1
105	14.1	6					moderate		2	0	0	0	0	1		$30,008	1

106	14.2	6					moderate		1	0	0	0	0	1		$27,606	
107	14.3	6					moderate		1	0	0	0	0	1		$29,199	1
108	14.4	6					moderate		1	0	0	0	0	1		$25,200	
109	14.5	6					high		1	0	0	0	0	1		$39,393	2
110	14.6	6					high		1	0	0	0	0	1		$36,385	1
111	14.7	6					high		1	0	0	0	0	1		$41,978	2
112	14.8	6					high		1	0	0	0	0	1		$44,173	2
113	14.9	6					high		1	0	0	0	0	1		$42,970	2
114	15.0	6					high		1	0	0	0	0	1		$43,571	2
115	15.1	6					high		1	0	0	0	0	1		$48,562	3
116	15.2	6					high		2	0	0	0	0	1		$51,960	3
117	15.3	6					high		2	0	0	0	0	1		$49,766	3
118	15.4	6					high		2	0	0	0	0	1		$51,570	3
119	15.5	6					high		2	0	0	0	0	1		$74,965	4
120	15.6	6					high		2	0	0	0	0	1		$59,569	4
121	15.7	6					high		2	0	0	0	0	1		$60,171	4
122	15.8	6					high		2	0	0	0	0	1		$57,374	3
123	15.9	6					high		1	0	0	0	0	1		$55,179	3
124	16.0	6					high		1	0	0	0	0	1		$61,585	4
125	16.1	6					high		2	0	0	0	0	1		$66,576	4
126	16.2	6					high		2	0	0	0	0	1		$60,984	4
127	16.3	6					high		2	0	0	0	0	1		$57,586	3
128	16.4	6					high		2	0	0	0	0	1		$56,984	3
129	16.5	6					moderate		2	0	0	0	0	1		$70,186	4
130	16.6	6					moderate		2	0	0	0	0	1		$43,392	2
131	16.7	6					moderate		1	0	0	0	0	1		$45,587	3
132	16.8	6					moderate		1	0	0	0	0	1		$42,791	2
133	16.9	6					moderate		1	0	0	0	0	1		$43,994	2
134	17.0	6					moderate		1	0	0	0	0	1		$43,392	2
135	17.1	6					moderate		1	0	0	0	0	1		$40,686	2
136	17.2	6					moderate		1	0	0	0	0	1		$34,953	1
137	17.3	6					moderate		1	0	0	0	0	1		$38,495	1
138	17.4	6					moderate		1	0	0	0	0	1		$39,600	2
139	17.5	6					moderate		1	0	0	0	0	1		$46,200	3
50	0.0	7					very high		6	0	0	1	0	0		$66,312	4
51	0.1	7					very high		5	0	0	1	0	0		$56,839	3
52	0.2	7					very high		4	0	0	1	0	0		$68,422	4
53	0.3	7					very high		3	0	0	1	0	0		$71,073	4
54	0.4	7					very high		3	0	0	1	0	0		$73,194	4
55	0.5	7					very high		3	0	0	1	0	0		$73,336	4
56	0.6	7					very high		2	0	0	1	0	0		$81,725	4

57	0.7	7					very high		2	0	0	1	0	0		$81,725	4
58	0.8	7					very high		2	0	0	1	0	0		$81,123	4
59	0.9	7					very high		2	0	0	1	0	0		$72,133	4
60	1.0	7					very high		2	0	0	1	0	0		$71,531	4
61	1.1	7					very high		2	0	0	1	0	0		$59,748	4
62	1.2	7					very high		2	0	0	1	0	0		$62,544	4
63	1.3	7					very high		2	0	0	1	0	0		$48,953	3
64	1.4	7					very high		2	0	0	1	0	0		$42,153	2
65	1.5	7					moderate		2	0	0	1	0	0		$46,754	3
66	1.6	7					moderate		2	0	0	1	0	0		$40,560	2
67	1.7	7					moderate		2	0	0	1	0	0		$32,171	1
68	1.8	7					moderate		2	0	0	1	0	0		$33,764	1
69	1.9	7					moderate		2	0	0	1	0	0		$36,560	1
70	2.0	7					moderate		2	0	0	1	0	0		$36,560	1
71	2.1	7					moderate		2	0	0	1	0	0		$28,171	
72	2.2	7					moderate		2	0	0	1	0	0		$27,570	
73	2.3	7					moderate		2	0	0	1	0	0		$25,375	
74	2.4	7					moderate		2	0	0	1	0	0		$28,773	
75	2.5	7							2	0	0	1	0	0		$32,386	1
76	2.6	7							2	0	0	1	0	0		$19,396	
77	2.7	7							2	0	0	1	0	0		$18,794	
1	2.8	7							2	1	0	1	0	0		$18,193	
2	2.9	7							2	1	0	1	0	0		$16,986	
3	3.0	7							2	1	0	1	0	0		$16,595	
4	3.1	7							2	1	0	1	0	0		$17,197	
5	3.2	7							2	1	0	1	0	0		$17,799	
6	3.3	7							2	1	0	1	0	0		$18,400	
7	3.4	7							2	1	0	1	0	0		$20,977	
8	3.5	7							2	1	0	1	0	0		$22,563	
9	3.6	7							2	1	0	1	0	0		$22,730	
10	3.7	7							2	1	0	1	0	0		$22,730	
11	3.8	7							2	1	0	1	0	0		$22,730	
12	3.9	7							2	1	0	1	0	0		$22,730	
13	4.0	7							2	1	0	1	0	0		$22,730	
14	4.1	7							2	1	0	1	0	0		$23,722	
15	4.2	7							2	1	0	1	0	0		$22,518	
16	4.3	7							2	1	0	1	0	0		$27,506	
17	4.4	7							2	1	0	1	0	0		$28,494	
18	4.5	7				moderate	moderate		2	1	0	1	0	0		$32,489	1
19	4.6	7				moderate	moderate		2	1	0	1	0	0		$27,506	
20	4.7	7				moderate	moderate		2	1	0	1	0	0		$23,725	

21	4.8	7				moderate	moderate		2	1	0	1	0	0			$23,725	
22	4.9	7				moderate	moderate		2	0	0	1	0	0			$23,725	
23	5.0	7				moderate	moderate		2	0	0	1	0	0			$29,701	1
24	5.1	7				moderate	moderate		2	0	0	0	0	0			$25,315	
25	5.2	7				moderate	moderate		2	0	0	0	0	0			$21,917	
26	5.3	7				moderate	moderate		2	0	0	0	0	0			$23,506	
27	5.4	7				moderate	moderate		2	0	0	0	0	0			$17,917	
28	5.5	7							2	0	0	0	0	0			$23,287	
29	5.6	7							2	0	0	0	0	0			$18,909	
30	5.7	7							2	0	0	0	0	0			$20,499	
31	5.8	7							2	0	0	0	0	0			$18,909	
32	5.9	7							2	0	0	0	0	0			$18,909	
33	6.0	7							2	0	0	0	0	0			$19,511	
34	6.1	7							2	0	0	0	0	0			$15,125	
35	6.2	7							2	0	0	0	0	0			$17,921	
36	6.3	7							2	0	0	0	0	0			$17,921	
37	6.4	7							2	0	0	0	0	0			$16,332	
38	6.5	7					moderate		2	0	0	0	0	0			$20,112	
39	6.6	7					moderate		2	0	0	0	0	0			$13,153	
40	6.7	7					moderate		2	0	0	0	0	0			$10,357	
41	6.8	7					moderate		1	0	0	0	0	0			$8,768	
42	6.9	7					moderate		1	0	0	0	0	0			$10,357	
43	7.0	7					moderate		1	0	0	0	0	0			$10,357	
44	7.1	7					moderate		1	0	0	0	0	0			$9,755	
45	7.2	7					moderate		1	0	0	0	0	0			$8,166	
46	7.3	7					moderate		1	0	0	0	0	0			$5,907	
47	7.4	7					moderate		1	0	0	0	0	0			$6,563	
48	7.5	7							1	0	0	0	0	0			$7,383	
49	7.6	7							1	0	0	0	0	0			$8,438	
0	7.7	7							1	0	0	0	0	0			$2,914	

20. APPENDIX I: RAW DATA FOR THE RANKING PROCESS AND SUGGESTED MITIGATION MEASURES PER 0.1 MI

			RANKING			MITIGATION SUGGESTION		
ID	Mi reference post	Hwy section	Human safety/Economics (%)	Biological conservation (%)	Final Ranking (%)	Crossing Opportunity	Barrier west/north side	Barrier east/south side
1	154.7	1	7.75	33.33	20.54		Fence	Fence
2	154.8	1	7.75	33.33	20.54		Fence	Fence
3	154.9	1	8.28	33.33	20.81		Fence	Fence
4	155.0	1	8.28	33.33	20.81	At-grade crossing	Fence	Fence
5	155.1	1	8.28	33.33	20.81		Fence	Fence
6	155.2	1	8.28	33.33	20.81		Fence	Fence
7	155.3	1	8.28	33.33	20.81		Fence	Fence
8	155.4	1	10.93	33.33	22.13		Fence	Fence
9	155.5	1	4.76	33.33	19.05		Fence	Fence
10	155.6	1	3.18	33.33	18.25		Fence	Fence
11	155.7	1	3.18	33.33	18.25		Fence	Fence
12	155.8	1	3.18	33.33	18.25		Fence	Fence
13	155.9	1	3.18	33.33	18.25		Fence	Fence
14	156.0	1	2.65	33.33	17.99	At-grade crossing	Fence	Fence
15	156.1	1	2.65	33.33	17.99		Fence	Fence
16	156.2	1	4.04	33.33	18.69		Fence	Fence
17	156.3	1	4.04	33.33	18.69		Fence	Fence
18	156.4	1	4.04	33.33	18.69		Fence	Fence
19	156.5	1	4.72	33.33	19.03		Fence	Fence
20	156.6	1	5.78	33.33	19.56		Fence	Fence
21	156.7	1	5.78	33.33	19.56		Fence	Fence
22	156.8	1	5.78	33.33	19.56		Fence	Fence
23	156.9	1	5.78	33.33	19.56		Fence	Fence
24	157.0	1	5.78	33.33	19.56	At-grade crossing	Fence	Fence
25	157.1	1	5.78	0.00	2.89		Fence	Fence
26	157.2	1	5.78	0.00	2.89		Fence	Fence
27	157.3	1	4.91	0.00	2.46		Fence	Fence
28	157.4	1	4.91	0.00	2.46		Fence	Fence
29	157.5	1	15.95	0.00	7.98		Fence	Fence
30	157.6	1	12.62	0.00	6.31		Fence	Fence
31	157.7	1	11.57	0.00	5.78		Fence	Fence

32	157.8	1	12.09	0.00	6.05		Fence	Fence
33	157.9	1	12.09	0.00	6.05		Fence	Fence
34	158.0	1	13.68	0.00	6.84	At-grade crossing	Fence	Fence
35	158.1	1	13.68	0.00	6.84		Fence	Fence
36	158.2	1	14.21	0.00	7.11		Fence	Fence
37	158.3	1	16.14	0.00	8.07		Fence	Fence
38	158.4	1	15.61	66.67	41.14		Fence	Fence
39	158.5	1	26.50	66.67	46.58		Fence	Fence
40	158.6	1	18.98	66.67	42.82		Fence	Fence
41	158.7	1	20.38	66.67	43.52		Fence	Fence
42	158.8	1	22.30	66.67	44.49		Fence	Fence
43	158.9	1	21.78	66.67	44.22		Fence	Fence
44	159.0	1	24.57	100.00	62.29	At-grade crossing	Fence	Fence
45	159.1	1	22.98	100.00	61.49		Fence	Fence
46	159.2	1	24.91	100.00	62.46		Fence	Fence
47	159.3	1	26.31	100.00	63.16		Fence	Fence
48	159.4	1	25.44	100.00	62.72		Fence	Fence
49	159.5	1	38.25	100.00	69.13		Fence	Fence
50	159.6	1	28.43	100.00	64.21		Fence	Fence
51	159.7	1	24.91	100.00	62.45		Fence	Fence
52	159.8	1	23.51	100.00	61.76		Fence	Fence
53	159.9	1	21.58	100.00	60.79		Fence	Fence
54	160.0	1	23.51	100.00	61.76	At-grade crossing	Fence	Fence
55	160.1	1	20.71	100.00	60.36		Fence	Fence
56	160.2	1	23.51	100.00	61.76		Fence	Fence
57	160.3	1	22.11	100.00	61.06		Fence	Fence
58	160.4	1	20.18	100.00	60.09		Fence	Fence
59	160.5	1	30.69	100.00	65.35		Fence	Fence
60	160.6	1	18.94	100.00	59.47		Fence	Fence
61	160.7	1	19.47	100.00	59.73		Fence	Fence
62	160.8	1	19.47	100.00	59.73		Fence	Fence
0	160.9	1	22.79	100.00	61.40		Fence	Fence
63	161.0	1	23.32	100.00	61.66	At-grade crossing	Fence	Fence
64	161.1	1	23.85	66.67	45.26		Fence	Fence
65	161.2	1	25.78	66.67	46.22		Fence	Fence
66	161.3	1	23.51	66.67	45.09		Fence	Fence
67	161.4	1	45.78	66.67	56.22		Fence	Fence
68	161.5	1	47.17	66.67	56.92		Fence	Fence
69	161.6	1	37.54	66.67	52.10		Fence	Fence
70	161.7	1	37.01	66.67	51.84		Fence	Fence
71	161.8	1	37.35	66.67	52.01		Fence	Fence

72	161.9	1	44.72	66.67	55.69		Fence	Fence
73	162.0	1	41.39	66.67	54.03	At-grade crossing	Fence	Fence
74	162.1	1	40.87	66.67	53.77		Fence	Fence
75	162.2	1	39.47	66.67	53.07		Fence	Fence
76	162.3	1	40.34	66.67	53.50		Fence	Fence
77	162.4	1	46.12	66.67	56.39		Fence	Fence
78	162.5	1	23.85	66.67	45.26		Fence	Fence
79	162.6	1	22.98	66.67	44.83		Fence	Fence
80	162.7	1	21.06	66.67	43.86		Fence	Fence
81	162.8	1	20.53	66.67	43.60		Fence	Fence
82	162.9	1	19.13	66.67	42.90		Fence	Fence
83	163.0	1	11.76	66.67	39.21	At-grade crossing	Fence	Fence
84	163.1	1	12.81	66.67	39.74		Fence	Fence
85	163.2	1	14.09	66.67	40.38		Fence	Fence
86	163.3	1	14.37	66.67	40.52		Fence	Fence
87	163.4	1	12.32	66.67	39.49		Fence	Fence
88	163.5	1	4.16	66.67	35.41		Fence	Fence
89	163.6	1	3.88	66.67	35.27		Fence	Fence
1	132.6	2	15.31	0.00	7.65		Fence	Fence
2	132.7	2	16.37	0.00	8.18		Fence	Fence
3	132.8	2	19.16	0.00	9.58		Fence	Fence
4	132.9	2	20.22	0.00	10.11		Fence	Fence
5	133.0	2	20.22	0.00	10.11		Fence	Fence
6	133.1	2	20.22	0.00	10.11		Fence	Fence
7	133.2	2	20.22	0.00	10.11		Fence	Fence
8	133.3	2	34.44	0.00	17.22		Fence	Fence
9	133.4	2	24.76	0.00	12.38		Fence	Fence
10	133.5	2	24.57	0.00	12.29		Fence	Fence
11	133.6	2	24.57	0.00	12.29		Fence	Fence
12	133.7	2	25.10	0.00	12.55		Fence	Fence
13	133.8	2	24.57	0.00	12.29		Fence	Fence
14	133.9	2	22.30	0.00	11.15		Fence	Fence
15	134.0	2	21.25	33.33	27.29	At-grade crossing	Fence	Fence
16	134.1	2	21.78	33.33	27.55		Fence	Fence
17	134.2	2	21.78	33.33	27.55		Fence	Fence
18	134.3	2	30.35	33.33	31.84		Fence	Fence
19	134.4	2	17.20	33.33	25.27		Fence	Fence
20	134.5	2	13.68	33.33	23.51		Fence	Fence
21	134.6	2	11.76	33.33	22.54		Fence	Fence
22	134.7	2	11.76	33.33	22.54		Fence	Fence
23	134.8	2	11.76	33.33	22.54		Fence	Fence

24	134.9	2	11.23	33.33	22.28		Fence	Fence
25	135.0	2	10.70	33.33	22.01	At-grade crossing	Fence	Fence
26	135.1	2	12.09	33.33	22.71		Fence	Fence
27	135.2	2	11.57	33.33	22.45		Fence	Fence
28	135.3	2	11.57	33.33	22.45		Fence	Fence
29	135.4	2	14.40	33.33	23.87		Fence	Fence
30	135.5	2	15.80	33.33	24.57		Fence	Fence
31	135.6	2	15.80	33.33	24.57		Fence	Fence
32	135.7	2	18.26	33.33	25.80		Fence	Fence
33	135.8	2	18.26	33.33	25.80		Fence	Fence
34	135.9	2	23.52	33.33	28.43		Fence	Fence
35	136.0	2	23.52	66.67	45.09	At-grade crossing	Fence	Fence
36	136.1	2	26.51	66.67	46.59		Fence	Fence
37	136.2	2	27.91	66.67	47.29		Fence	Fence
38	136.3	2	28.44	66.67	47.55		Fence	Fence
39	136.4	2	43.52	66.67	55.09		Fence	Fence
40	136.5	2	33.50	66.67	50.08		Fence	Fence
41	136.6	2	31.57	66.67	49.12		Fence	Fence
42	136.7	2	32.97	66.67	49.82		Fence	Fence
43	136.8	2	30.51	66.67	48.59		Fence	Fence
44	136.9	2	31.91	66.67	49.29		Fence	Fence
45	137.0	2	27.52	66.67	47.09	At-grade crossing	Fence	Fence
46	137.1	2	28.05	66.67	47.36		Fence	Fence
47	137.2	2	25.06	66.67	45.86		Fence	Fence
48	137.3	2	22.26	66.67	44.46		Fence	Fence
49	137.4	2	43.16	66.67	54.92		Fence	Fence
50	137.5	2	33.00	66.67	49.83		Fence	Fence
51	137.6	2	36.18	66.67	51.42		Fence	Fence
52	137.7	2	36.18	66.67	51.42		Fence	Fence
53	137.8	2	36.18	66.67	51.42		Fence	Fence
54	137.9	2	36.71	66.67	51.69		Fence	Fence
55	138.0	2	35.31	66.67	50.99	At-grade crossing	Fence	Fence
56	138.1	2	33.91	0.00	16.95		Fence	Fence
57	138.2	2	34.78	0.00	17.39		Fence	Fence
58	138.3	2	34.78	0.00	17.39		Fence	Fence
59	138.4	2	50.28	0.00	25.14		Fence	Fence
60	138.5	2	29.37	0.00	14.69		Fence	Fence
61	138.6	2	24.99	0.00	12.49		Fence	Fence
62	138.7	2	20.41	0.00	10.21		Fence	Fence
63	138.8	2	19.88	0.00	9.94		Fence	Fence
64	138.9	2	24.12	0.00	12.06		Fence	Fence

65	139.0	2	23.59	0.00	11.79	At-grade crossing	Fence	Fence
66	139.1	2	24.12	0.00	12.06		Fence	Fence
67	139.2	2	26.23	0.00	13.12		Fence	Fence
68	139.3	2	25.37	0.00	12.68		Fence	Fence
69	139.4	2	40.86	0.00	20.43		Fence	Fence
70	139.5	2	25.89	0.00	12.95		Fence	Fence
71	139.6	2	25.89	0.00	12.95		Fence	Fence
72	139.7	2	25.89	0.00	12.95		Fence	Fence
73	139.8	2	25.89	0.00	12.95		Fence	Fence
74	139.9	2	30.47	0.00	15.23		Fence	Fence
75	140.0	2	25.89	33.33	29.61	At-grade crossing	Fence	Fence
76	140.1	2	27.48	33.33	30.41		Fence	Fence
77	140.2	2	26.95	33.33	30.14		Fence	Fence
78	140.3	2	25.37	33.33	29.35		Fence	Fence
79	140.4	2	24.84	33.33	29.08		Fence	Fence
80	140.5	2	17.09	33.33	25.21		Fence	Fence
81	140.6	2	16.56	33.33	24.95		Fence	Fence
82	140.7	2	16.56	33.33	24.95		Fence	Fence
83	140.8	2	17.09	33.33	25.21		Fence	Fence
84	140.9	2	17.62	33.33	25.47		Fence	Fence
85	141.0	2	14.97	33.33	24.15	At-grade crossing	Fence	Fence
86	141.1	2	14.44	33.33	23.89		Fence	Fence
3	141.2	3	13.91	33.33	23.62		Mitigation already scheduled	Mitigation already scheduled
4	141.3	3	14.97	33.33	24.15		Mitigation already scheduled	Mitigation already scheduled
5	141.4	3	17.09	33.33	25.21		Mitigation already scheduled	Mitigation already scheduled
6	141.5	3	35.42	33.33	34.38		Mitigation already scheduled	Mitigation already scheduled
7	141.6	3	28.73	33.33	31.03		Mitigation already scheduled	Mitigation already scheduled
8	141.7	3	29.26	33.33	31.30		Mitigation already scheduled	Mitigation already scheduled
9	141.8	3	30.32	33.33	31.83		Mitigation already scheduled	Mitigation already scheduled
10	141.9	3	30.32	33.33	31.83		Mitigation already scheduled	Mitigation already scheduled
11	142.0	3	38.07	33.33	35.70		Mitigation already scheduled	Mitigation already scheduled
12	142.1	3	37.20	33.33	35.27		Mitigation already scheduled	Mitigation already scheduled
13	142.2	3	39.65	33.33	36.49		Mitigation already scheduled	Mitigation already scheduled
14	142.3	3	39.13	33.33	36.23		Mitigation already scheduled	Mitigation already scheduled
15	142.4	3	40.52	33.33	36.93		Mitigation already scheduled	Mitigation already scheduled
16	142.5	3	54.44	33.33	43.88		Mitigation already scheduled	Mitigation already scheduled
17	142.6	3	37.69	33.33	35.51		Mitigation already scheduled	Mitigation already scheduled
18	142.7	3	38.75	33.33	36.04		Mitigation already scheduled	Mitigation already scheduled
19	142.8	3	40.86	33.33	37.10		Mitigation already scheduled	Mitigation already scheduled
20	142.9	3	39.81	33.33	36.57		Mitigation already scheduled	Mitigation already scheduled
21	143.0	3	41.92	33.33	37.63		Mitigation already scheduled	Mitigation already scheduled

22	143.1	3	34.17	33.33	33.75		Mitigation already scheduled	Mitigation already scheduled
23	143.2	3	33.11	33.33	33.22		Mitigation already scheduled	Mitigation already scheduled
24	143.3	3	32.77	33.33	33.05		Mitigation already scheduled	Mitigation already scheduled
25	143.4	3	33.30	33.33	33.32		Mitigation already scheduled	Mitigation already scheduled
26	143.5	3	41.59	33.33	37.46		Mitigation already scheduled	Mitigation already scheduled
27	143.6	3	26.43	0.00	13.22		Mitigation already scheduled	Mitigation already scheduled
28	143.7	3	25.90	0.00	12.95		Mitigation already scheduled	Mitigation already scheduled
29	143.8	3	23.78	0.00	11.89		Mitigation already scheduled	Mitigation already scheduled
30	143.9	3	21.14	0.00	10.57		Mitigation already scheduled	Mitigation already scheduled
31	144.0	3	23.07	0.00	11.53		Mitigation already scheduled	Mitigation already scheduled
32	144.1	3	19.89	0.00	9.95		Mitigation already scheduled	Mitigation already scheduled
33	144.2	3	19.89	0.00	9.95		Mitigation already scheduled	Mitigation already scheduled
34	144.3	3	21.29	0.00	10.64		Mitigation already scheduled	Mitigation already scheduled
35	144.4	3	20.04	0.00	10.02		Mitigation already scheduled	Mitigation already scheduled
36	144.5	3	25.33	0.00	12.67		Mitigation already scheduled	Mitigation already scheduled
37	144.6	3	14.59	0.00	7.30		Mitigation already scheduled	Mitigation already scheduled
38	144.7	3	13.72	0.00	6.86		Mitigation already scheduled	Mitigation already scheduled
39	144.8	3	12.66	0.00	6.33		Mitigation already scheduled	Mitigation already scheduled
40	144.9	3	14.06	0.00	7.03		Mitigation already scheduled	Mitigation already scheduled
41	145.0	3	15.65	0.00	7.82		Mitigation already scheduled	Mitigation already scheduled
42	145.1	3	13.19	0.00	6.60		Mitigation already scheduled	Mitigation already scheduled
43	145.2	3	13.19	0.00	6.60		Mitigation already scheduled	Mitigation already scheduled
44	145.3	3	13.19	0.00	6.60		Mitigation already scheduled	Mitigation already scheduled
45	145.4	3	12.32	0.00	6.16		Mitigation already scheduled	Mitigation already scheduled
46	145.5	3	37.36	0.00	18.68		Mitigation already scheduled	Mitigation already scheduled
47	145.6	3	34.52	33.33	33.93		Mitigation already scheduled	Mitigation already scheduled
48	145.7	3	39.96	33.33	36.65		Mitigation already scheduled	Mitigation already scheduled
49	145.8	3	42.95	33.33	38.14		Mitigation already scheduled	Mitigation already scheduled
50	145.9	3	43.48	33.33	38.41		Mitigation already scheduled	Mitigation already scheduled
51	146.0	3	53.50	33.33	43.42		Mitigation already scheduled	Mitigation already scheduled
52	146.1	3	55.24	66.67	60.95		Mitigation already scheduled	Mitigation already scheduled
53	146.2	3	57.69	66.67	62.18		Mitigation already scheduled	Mitigation already scheduled
54	146.3	3	63.67	66.67	65.17		Mitigation already scheduled	Mitigation already scheduled
55	146.4	3	66.12	66.67	66.39		Mitigation already scheduled	Mitigation already scheduled
56	146.5	3	98.78	66.67	82.73		Mitigation already scheduled	Mitigation already scheduled
57	146.6	3	79.01	66.67	72.84		Mitigation already scheduled	Mitigation already scheduled
58	146.7	3	82.33	66.67	74.50		Mitigation already scheduled	Mitigation already scheduled
59	146.8	3	78.29	66.67	72.48		Mitigation already scheduled	Mitigation already scheduled
60	146.9	3	76.70	66.67	71.68		Mitigation already scheduled	Mitigation already scheduled
61	147.0	3	82.33	66.67	74.50		Mitigation already scheduled	Mitigation already scheduled
62	147.1	3	74.09	66.67	70.38		Mitigation already scheduled	Mitigation already scheduled

63	147.2	3	75.15	66.67	70.91		Mitigation already scheduled	Mitigation already scheduled
64	147.3	3	75.15	66.67	70.91		Mitigation already scheduled	Mitigation already scheduled
65	147.4	3	71.10	66.67	68.88		Mitigation already scheduled	Mitigation already scheduled
66	147.5	3	88.49	66.67	77.58		Mitigation already scheduled	Mitigation already scheduled
67	147.6	3	55.30	33.33	44.32		Mitigation already scheduled	Mitigation already scheduled
68	147.7	3	50.24	33.33	41.79		Mitigation already scheduled	Mitigation already scheduled
69	147.8	3	43.93	33.33	38.63		Mitigation already scheduled	Mitigation already scheduled
70	147.9	3	42.53	33.33	37.93		Mitigation already scheduled	Mitigation already scheduled
71	148.0	3	41.13	33.33	37.23		Mitigation already scheduled	Mitigation already scheduled
72	148.1	3	36.37	33.33	34.85		Mitigation already scheduled	Mitigation already scheduled
73	148.2	3	33.72	33.33	33.53		Mitigation already scheduled	Mitigation already scheduled
74	148.3	3	29.86	33.33	31.60		Mitigation already scheduled	Mitigation already scheduled
75	148.4	3	27.41	33.33	30.37		Mitigation already scheduled	Mitigation already scheduled
76	148.5	3	39.58	33.33	36.46		Mitigation already scheduled	Mitigation already scheduled
77	148.6	3	19.74	33.33	26.53		Mitigation already scheduled	Mitigation already scheduled
78	148.7	3	22.73	33.33	28.03		Mitigation already scheduled	Mitigation already scheduled
79	148.8	3	22.20	0.00	11.10		Fence	Fence
80	148.9	3	21.67	0.00	10.83		Fence	Fence
81	149.0	3	24.31	0.00	12.16		Fence	Fence
82	149.1	3	23.78	0.00	11.89		Fence	Fence
83	149.2	3	26.43	0.00	13.22		Fence	Fence
84	149.3	3	28.02	0.00	14.01		Fence	Fence
85	149.4	3	31.72	0.00	15.86		Fence	Fence
86	149.5	3	64.13	0.00	32.06		Fence	Fence
87	149.6	3	51.95	33.33	42.64		Fence	Fence
88	149.7	3	56.53	33.33	44.93		Fence	Fence
89	149.8	3	54.60	33.33	43.97		Fence	Fence
90	149.9	3	57.25	33.33	45.29		Fence	Fence
91	150.0	3	62.35	33.33	47.84		Fence	Fence
92	150.1	3	62.16	33.33	47.75		Fence	Fence
93	150.2	3	63.22	33.33	48.28		Fence	Fence
94	150.3	3	63.75	33.33	48.54		Fence	Fence
95	150.4	3	63.75	33.33	48.54		Fence	Fence
96	150.5	3	79.06	33.33	56.19		Fence	Fence
97	150.6	3	47.71	33.33	40.52		Fence	Fence
98	150.7	3	50.88	33.33	42.11		Fence	Fence
99	150.8	3	49.10	33.33	41.22		Fence	Fence
100	150.9	3	48.57	33.33	40.95	Overpass		
101	151.0	3	67.51	33.33	50.42		Fence	Fence
102	151.1	3	66.46	33.33	49.89		Fence	Fence
103	151.2	3	70.50	33.33	51.92		Fence	Fence

104	151.3	3	75.42	33.33	54.38		Fence	Fence
105	151.4	3	73.49	33.33	53.41		Fence	Fence
106	151.5	3	90.74	33.33	62.04		Fence	Fence
107	151.6	3	73.31	33.33	53.32		Fence	Fence
108	151.7	3	78.42	33.33	55.88		Fence	Fence
109	151.8	3	77.37	33.33	55.35		Fence	Fence
110	151.9	3	77.74	33.33	55.54		Fence	Fence
111	152.0	3	84.10	33.33	58.71			
112	152.1	3	62.51	33.33	47.92			
113	152.2	3	58.99	33.33	46.16			
114	152.3	3	62.52	33.33	47.92			
115	152.4	3	59.72	33.33	46.52			
116	152.5	3	82.29	33.33	57.81			
117	152.6	3	65.57	33.33	49.45			
118	152.7	3	65.57	33.33	49.45			
119	152.8	3	60.99	33.33	47.16			
120	152.9	3	61.18	33.33	47.26			
121	153.0	3	71.23	33.33	52.28		Fence	
2	153.1	4	76.87	33.33	55.10		Fence	
3	153.2	4	83.75	33.33	58.54		Fence	
4	153.3	4	88.51	33.33	60.92		Fence	
5	153.4	4	86.95	33.33	60.14		Fence	
6	153.5	4	100.00	33.33	66.67		Fence	Fence
7	153.6	4	75.84	33.33	54.59	Overpass		
8	153.7	4	73.19	33.33	53.26		Fence	Retaining wall
9	153.8	4	71.08	33.33	52.21		Fence	Retaining wall
10	153.9	4	69.49	33.33	51.41		Fence	Retaining wall
11	154.0	4	65.26	33.33	49.29		Fence	
12	154.1	4	52.02	33.33	42.68		Fence	
13	154.2	4	39.51	33.33	36.42		Fence	
14	154.3	4	33.16	33.33	33.25		Fence	
15	154.4	4	28.39	33.33	30.86		Fence	
16	154.5	4	33.12	33.33	33.23			
17	154.6	4	17.96	33.33	25.65			
18	154.7	4	21.14	33.33	27.24	At-grade crossing		
19	154.8	4	23.07	33.33	28.20	At-grade crossing		
20	154.9	4	23.07	33.33	28.20	At-grade crossing	fence	fence
21	155.0	4	24.65	66.67	45.66		fence	fence
22	155.1	4	26.24	66.67	46.45		fence	fence
23	155.2	4	26.24	66.67	46.45		fence	fence
24	155.3	4	26.77	66.67	46.72		fence	fence

25	155.4	4	25.18	66.67	45.92		fence	fence
26	155.5	4	36.79	66.67	51.73		fence	fence
27	155.6	4	23.59	66.67	45.13		fence	fence
28	155.7	4	24.12	66.67	45.39		fence	fence
29	155.8	4	23.21	33.33	28.27		fence	fence
30	155.9	4	21.28	33.33	27.31		fence	fence
31	156.0	4	25.67	33.33	29.50		fence	fence
32	156.1	4	24.08	33.33	28.71		fence	fence
33	156.2	4	23.02	33.33	28.18		fence	fence
34	156.3	4	23.89	33.33	28.61		fence	fence
35	156.4	4	24.42	33.33	28.88		fence	fence
36	156.5	4	45.13	33.33	39.23		fence	fence
37	156.6	4	33.53	33.33	33.43		fence	fence
38	156.7	4	33.53	33.33	33.43		fence	fence
39	156.8	4	33.34	33.33	33.34		fence	fence
40	156.9	4	35.80	33.33	34.57		fence	fence
41	157.0	4	46.30	33.33	39.82		fence	fence
42	157.1	4	45.78	33.33	39.55		fence	fence
43	157.2	4	49.10	33.33	41.22		fence	fence
44	157.3	4	53.83	33.33	43.58		fence	fence
45	157.4	4	54.36	33.33	43.85		fence	fence
46	157.5	4	73.00	33.33	53.17		fence	fence
47	157.6	4	56.33	33.33	44.83		fence	fence
48	157.7	4	63.18	33.33	48.26		fence	fence
49	157.8	4	64.76	33.33	49.05		fence	fence
50	157.9	4	63.90	33.33	48.61		fence	fence
51	158.0	4	62.15	33.33	47.74		fence	fence
52	158.1	4	53.57	33.33	43.45		fence	fence
53	158.2	4	50.25	33.33	41.79		fence	fence
54	158.3	4	47.45	33.33	40.39	Underpass	fence	fence
55	158.4	4	42.19	33.33	37.76		fence	fence
56	158.5	4	40.27	33.33	36.80		fence	fence
57	158.6	4	20.57	33.33	26.95		fence	fence
58	158.7	4	17.05	33.33	25.19		fence	fence
59	158.8	4	9.68	33.33	21.51		Adjacent to National Park	Adjacent to National Park
60	158.9	4	8.09	33.33	20.71		Adjacent to National Park	Adjacent to National Park
61	159.0	4	7.56	33.33	20.45		Adjacent to National Park	Adjacent to National Park
62	159.1	4	4.04	33.33	18.69		Adjacent to National Park	Adjacent to National Park
63	159.2	4	2.12	33.33	17.73		Adjacent to National Park	Adjacent to National Park
64	159.3	4	1.59	33.33	17.46		Adjacent to National Park	Adjacent to National Park
65	159.4	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park

66	159.5	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park
67	159.6	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park
68	159.7	4	1.59	33.33	17.46		Adjacent to National Park	Adjacent to National Park
69	159.8	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park
70	159.9	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park
71	160.0	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park
72	160.1	4	1.06	33.33	17.20		Adjacent to National Park	Adjacent to National Park
73	160.2	4	7.38	33.33	20.36		Adjacent to National Park	Adjacent to National Park
74	160.3	4	7.91	33.33	20.62		Adjacent to National Park	Adjacent to National Park
75	160.4	4	8.70	33.33	21.02		Adjacent to National Park	Adjacent to National Park
76	160.5	4	9.66	33.33	21.50		Adjacent to National Park	Adjacent to National Park
77	160.6	4	10.87	33.33	22.10		Adjacent to National Park	Adjacent to National Park
78	160.7	4	12.42	33.33	22.88		Adjacent to National Park	Adjacent to National Park
79	160.8	4	13.53	33.33	23.43		Adjacent to National Park	Adjacent to National Park
1	2.0	5	6.10	33.33	19.72		Recently locally mitigated	Recently locally mitigated
2	2.1	5	5.23	33.33	19.28		Recently locally mitigated	Recently locally mitigated
3	2.2	5	4.57	33.33	18.95		Recently locally mitigated	Recently locally mitigated
4	2.3	5	4.71	33.33	19.02		Recently locally mitigated	Recently locally mitigated
5	2.4	5	4.24	33.33	18.79		Recently locally mitigated	Recently locally mitigated
6	2.5	5	3.86	33.33	18.59		Recently locally mitigated	Recently locally mitigated
7	2.6	5	3.86	66.67	35.26		Recently locally mitigated	Recently locally mitigated
8	2.7	5	5.25	66.67	35.96		Recently locally mitigated	Recently locally mitigated
9	2.8	5	5.25	66.67	35.96		Recently locally mitigated	Recently locally mitigated
10	2.9	5	3.86	66.67	35.26		Recently locally mitigated	Recently locally mitigated
11	3.0	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
12	3.1	5	1.93	33.33	17.63		Recently locally mitigated	Recently locally mitigated
13	3.2	5	1.93	66.67	34.30		Recently locally mitigated	Recently locally mitigated
14	3.3	5	1.93	66.67	34.30		Recently locally mitigated	Recently locally mitigated
15	3.4	5	1.40	66.67	34.03		Recently locally mitigated	Recently locally mitigated
16	3.5	5	1.40	66.67	34.03		Recently locally mitigated	Recently locally mitigated
17	3.6	5	1.40	66.67	34.03		Recently locally mitigated	Recently locally mitigated
18	3.7	5	1.40	66.67	34.03		Recently locally mitigated	Recently locally mitigated
19	3.8	5	0.00	66.67	33.33		Recently locally mitigated	Recently locally mitigated
20	3.9	5	0.00	66.67	33.33		Recently locally mitigated	Recently locally mitigated
21	4.0	5	0.00	66.67	33.33		Recently locally mitigated	Recently locally mitigated
22	4.1	5	0.00	66.67	33.33		Recently locally mitigated	Recently locally mitigated
23	4.2	5	0.00	66.67	33.33		Recently locally mitigated	Recently locally mitigated
24	4.3	5	0.00	66.67	33.33		Recently locally mitigated	Recently locally mitigated
25	4.4	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
26	4.5	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
94	4.6	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated

95	4.7	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
96	4.8	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
97	4.9	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
98	5.0	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
99	5.1	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
100	5.2	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
101	5.3	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
102	5.4	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
103	5.5	5	4.72	33.33	19.03		Recently locally mitigated	Recently locally mitigated
104	5.6	5	1.40	33.33	17.37		Recently locally mitigated	Recently locally mitigated
105	5.7	5	1.40	33.33	17.37		Recently locally mitigated	Recently locally mitigated
106	5.8	5	1.40	33.33	17.37		Recently locally mitigated	Recently locally mitigated
107	5.9	5	1.40	33.33	17.37		Recently locally mitigated	Recently locally mitigated
108	6.0	5	1.40	66.67	34.03		Recently locally mitigated	Recently locally mitigated
109	6.1	5	1.40	66.67	34.03		Recently locally mitigated	Recently locally mitigated
110	6.2	5	2.80	66.67	34.73		Recently locally mitigated	Recently locally mitigated
111	6.3	5	5.59	66.67	36.13		Recently locally mitigated	Recently locally mitigated
112	6.4	5	5.59	66.67	36.13		Recently locally mitigated	Recently locally mitigated
113	6.5	5	8.05	33.33	20.69		Recently locally mitigated	Recently locally mitigated
114	6.6	5	9.11	33.33	21.22		Recently locally mitigated	Recently locally mitigated
115	6.7	5	9.11	33.33	21.22		Recently locally mitigated	Recently locally mitigated
116	6.8	5	9.11	33.33	21.22		Recently locally mitigated	Recently locally mitigated
117	6.9	5	10.51	33.33	21.92		Recently locally mitigated	Recently locally mitigated
118	7.0	5	13.31	66.67	39.99		Recently locally mitigated	Recently locally mitigated
119	7.1	5	13.31	66.67	39.99		Recently locally mitigated	Recently locally mitigated
120	7.2	5	13.84	66.67	40.25		Recently locally mitigated	Recently locally mitigated
121	7.3	5	12.44	66.67	39.55		Recently locally mitigated	Recently locally mitigated
122	7.4	5	9.64	66.67	38.15		Recently locally mitigated	Recently locally mitigated
123	7.5	5	9.64	66.67	38.15		Recently locally mitigated	Recently locally mitigated
124	7.6	5	7.18	66.67	36.93		Recently locally mitigated	Recently locally mitigated
125	7.7	5	5.25	66.67	35.96		Recently locally mitigated	Recently locally mitigated
126	7.8	5	5.25	66.67	35.96		Recently locally mitigated	Recently locally mitigated
127	7.9	5	6.65	66.67	36.66		Recently locally mitigated	Recently locally mitigated
128	8.0	5	6.31	100.00	53.16		Recently locally mitigated	Recently locally mitigated
129	8.1	5	3.52	100.00	51.76		Recently locally mitigated	Recently locally mitigated
130	8.2	5	4.04	100.00	52.02		Recently locally mitigated	Recently locally mitigated
131	8.3	5	3.52	100.00	51.76		Recently locally mitigated	Recently locally mitigated
132	8.4	5	3.52	100.00	51.76		Recently locally mitigated	Recently locally mitigated
133	8.5	5	4.57	100.00	52.29		Recently locally mitigated	Recently locally mitigated
134	8.6	5	4.57	100.00	52.29		Recently locally mitigated	Recently locally mitigated
135	8.7	5	4.57	100.00	52.29		Recently locally mitigated	Recently locally mitigated

136	8.8	5	4.04	100.00	52.02		Recently locally mitigated	Recently locally mitigated
137	8.9	5	4.04	66.67	35.36		Recently locally mitigated	Recently locally mitigated
138	9.0	5	2.65	66.67	34.66		Recently locally mitigated	Recently locally mitigated
139	9.1	5	1.59	66.67	34.13		Recently locally mitigated	Recently locally mitigated
140	9.2	5	1.59	66.67	34.13		Recently locally mitigated	Recently locally mitigated
141	9.3	5	1.59	66.67	34.13		Recently locally mitigated	Recently locally mitigated
142	9.4	5	1.59	66.67	34.13		Recently locally mitigated	Recently locally mitigated
143	9.5	5	5.97	66.67	36.32		Recently locally mitigated	Recently locally mitigated
144	9.6	5	4.91	66.67	35.79		Recently locally mitigated	Recently locally mitigated
145	9.7	5	4.91	66.67	35.79		Recently locally mitigated	Recently locally mitigated
146	9.8	5	4.91	66.67	35.79		Recently locally mitigated	Recently locally mitigated
147	9.9	5	4.91	33.33	19.12		Recently locally mitigated	Recently locally mitigated
148	10.0	5	5.44	33.33	19.39		Recently locally mitigated	Recently locally mitigated
149	10.1	5	5.44	33.33	19.39		Recently locally mitigated	Recently locally mitigated
150	10.2	5	5.44	33.33	19.39		Recently locally mitigated	Recently locally mitigated
151	10.3	5	5.44	33.33	19.39		Recently locally mitigated	Recently locally mitigated
152	10.4	5	4.91	33.33	19.12		Recently locally mitigated	Recently locally mitigated
153	10.5	5	4.91	33.33	19.12		Recently locally mitigated	Recently locally mitigated
154	10.6	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
155	10.7	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
156	10.8	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
157	10.9	5	1.93	33.33	17.63		Recently locally mitigated	Recently locally mitigated
158	11.0	5	3.33	33.33	18.33		Recently locally mitigated	Recently locally mitigated
159	11.1	5	2.80	33.33	18.07		Recently locally mitigated	Recently locally mitigated
160	11.2	5	2.80	33.33	18.07		Recently locally mitigated	Recently locally mitigated
161	11.3	5	2.80	33.33	18.07		Recently locally mitigated	Recently locally mitigated
162	11.4	5	2.80	33.33	18.07		Recently locally mitigated	Recently locally mitigated
163	11.5	5	5.79	33.33	19.56		Recently locally mitigated	Recently locally mitigated
164	11.6	5	5.79	33.33	19.56		Recently locally mitigated	Recently locally mitigated
165	11.7	5	5.79	33.33	19.56		Recently locally mitigated	Recently locally mitigated
166	11.8	5	5.79	33.33	19.56		Recently locally mitigated	Recently locally mitigated
167	11.9	5	5.79	33.33	19.56		Recently locally mitigated	Recently locally mitigated
168	12.0	5	4.39	33.33	18.86		Recently locally mitigated	Recently locally mitigated
169	12.1	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
170	12.2	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
171	12.3	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
172	12.4	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
173	12.5	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
174	12.6	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
175	12.7	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
176	12.8	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated

177	12.9	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
178	13.0	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
179	13.1	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
180	13.2	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
181	13.3	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
182	13.4	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
183	13.5	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
184	13.6	5	2.65	33.33	17.99		Recently locally mitigated	Recently locally mitigated
185	13.7	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
186	13.8	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
187	13.9	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
188	14.0	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
189	14.1	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
190	14.2	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
191	14.3	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
192	14.4	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
193	14.5	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
194	14.6	5	2.65	33.33	17.99		Recently locally mitigated	Recently locally mitigated
195	14.7	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
196	14.8	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
197	14.9	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
198	15.0	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
199	15.1	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
200	15.2	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
201	15.3	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
202	15.4	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
203	15.5	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
204	15.6	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
205	15.7	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
206	15.8	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
207	15.9	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
208	16.0	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
209	16.1	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
210	16.2	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
211	16.3	5	2.65	33.33	17.99		Recently locally mitigated	Recently locally mitigated
212	16.4	5	2.65	33.33	17.99		Recently locally mitigated	Recently locally mitigated
213	16.5	5	2.65	33.33	17.99		Recently locally mitigated	Recently locally mitigated
214	16.6	5	3.18	33.33	18.25		Recently locally mitigated	Recently locally mitigated
215	16.7	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
216	16.8	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
217	16.9	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated

218	17.0	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
219	17.1	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
220	17.2	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
221	17.3	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
1	17.4	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
2	17.5	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
3	17.6	5	3.52	33.33	18.42		Recently locally mitigated	Recently locally mitigated
4	17.7	5	3.52	33.33	18.42		Recently locally mitigated	Recently locally mitigated
5	17.8	5	3.52	33.33	18.42		Recently locally mitigated	Recently locally mitigated
6	17.9	5	3.52	33.33	18.42		Recently locally mitigated	Recently locally mitigated
7	18.0	5	3.52	33.33	18.42		Recently locally mitigated	Recently locally mitigated
8	18.1	5	4.04	33.33	18.69		Recently locally mitigated	Recently locally mitigated
9	18.2	5	4.57	33.33	18.95		Recently locally mitigated	Recently locally mitigated
10	18.3	5	4.57	33.33	18.95		Recently locally mitigated	Recently locally mitigated
11	18.4	5	4.57	33.33	18.95		Recently locally mitigated	Recently locally mitigated
12	18.5	5	4.04	33.33	18.69		Recently locally mitigated	Recently locally mitigated
13	18.6	5	4.04	33.33	18.69		Recently locally mitigated	Recently locally mitigated
14	18.7	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
15	18.8	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
16	18.9	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
17	19.0	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
18	19.1	5	2.99	33.33	18.16		Recently locally mitigated	Recently locally mitigated
19	19.2	5	1.93	33.33	17.63		Recently locally mitigated	Recently locally mitigated
20	19.3	5	1.40	33.33	17.37		Recently locally mitigated	Recently locally mitigated
21	19.4	5	1.40	33.33	17.37		Recently locally mitigated	Recently locally mitigated
22	19.5	5	1.93	33.33	17.63		Recently locally mitigated	Recently locally mitigated
23	19.6	5	3.86	33.33	18.59		Recently locally mitigated	Recently locally mitigated
24	19.7	5	3.86	33.33	18.59		Recently locally mitigated	Recently locally mitigated
25	19.8	5	3.86	33.33	18.59		Recently locally mitigated	Recently locally mitigated
26	19.9	5	3.86	33.33	18.59		Recently locally mitigated	Recently locally mitigated
27	20.0	5	3.86	33.33	18.59		Recently locally mitigated	Recently locally mitigated
28	20.1	5	2.46	33.33	17.90		Recently locally mitigated	Recently locally mitigated
29	20.2	5	2.46	33.33	17.90		Recently locally mitigated	Recently locally mitigated
30	20.3	5	2.46	33.33	17.90		Recently locally mitigated	Recently locally mitigated
31	20.4	5	2.46	33.33	17.90		Recently locally mitigated	Recently locally mitigated
32	20.5	5	2.46	33.33	17.90		Recently locally mitigated	Recently locally mitigated
33	20.6	5	2.46	33.33	17.90		Recently locally mitigated	Recently locally mitigated
34	20.7	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
35	20.8	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
36	20.9	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
37	21.0	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated

38	21.1	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
39	21.2	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
40	21.3	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
41	21.4	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
42	21.5	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
43	21.6	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
44	21.7	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
45	21.8	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
46	21.9	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
47	22.0	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
48	22.1	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
49	22.2	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
50	22.3	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
51	22.4	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
52	22.5	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
53	22.6	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
54	22.7	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
55	22.8	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
56	22.9	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
57	23.0	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
58	23.1	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
59	23.2	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
60	23.3	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
61	23.4	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
62	23.5	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
63	23.6	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
64	23.7	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
65	23.8	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
66	23.9	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
67	24.0	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
68	24.1	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
69	24.2	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
70	24.3	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
71	24.4	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
72	24.5	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
73	24.6	5	1.06	33.33	17.20		Recently locally mitigated	Recently locally mitigated
74	24.7	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
75	24.8	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
76	24.9	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
77	25.0	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated
78	25.1	5	0.53	33.33	16.93		Recently locally mitigated	Recently locally mitigated

79	25.2	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
80	25.3	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
81	25.4	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
82	25.5	5	1.59	33.33	17.46		Recently locally mitigated	Recently locally mitigated
83	25.6	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
84	25.7	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
85	25.8	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
86	25.9	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
87	26.0	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
88	26.1	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
89	26.2	5	2.12	33.33	17.73		Recently locally mitigated	Recently locally mitigated
90	26.3	5	1.16	33.33	17.25		Recently locally mitigated	Recently locally mitigated
91	26.4	5	1.29	33.33	17.31		Recently locally mitigated	Recently locally mitigated
92	26.5	5	1.46	33.33	17.39		Recently locally mitigated	Recently locally mitigated
93	26.6	5	0.83	33.33	17.08		Recently locally mitigated	Recently locally mitigated
0	26.7	5	0.00	33.33	16.67		Recently locally mitigated	Recently locally mitigated
141	0.0	6	31.95	33.33	32.64		fence	fence
142	0.1	6	28.22	33.33	30.77		fence	fence
143	0.2	6	29.26	33.33	31.30		fence	fence
144	0.3	6	34.14	33.33	33.74		fence	fence
145	0.4	6	31.89	33.33	32.61		fence	fence
146	0.5	6	42.71	33.33	38.02		Retaining wall	Retaining wall
147	0.6	6	51.29	33.33	42.31		Retaining wall	Retaining wall
148	0.7	6	52.31	33.33	42.82	Underpass	Retaining wall	Retaining wall
149	0.8	6	54.05	66.67	60.36		Retaining wall	Retaining wall
150	0.9	6	59.31	66.67	62.99		fence	Retaining wall
151	1.0	6	64.56	66.67	65.61	Overpass	fence	Retaining wall
152	1.1	6	62.26	66.67	64.46		fence	Retaining wall
153	1.2	6	72.96	66.67	69.81		fence	Retaining wall
154	1.3	6	72.28	66.67	69.47		fence	Retaining wall
155	1.4	6	71.75	66.67	69.21		fence	Retaining wall
156	1.5	6	99.47	66.67	83.07		fence	Retaining wall
157	1.6	6	91.73	66.67	79.20		fence	Retaining wall
158	1.7	6	84.73	66.67	75.70		Retaining wall	Retaining wall
159	1.8	6	82.81	100.00	91.40		Retaining wall	Retaining wall
160	1.9	6	78.42	100.00	89.21	Overpass	fence	fence
161	2.0	6	74.03	100.00	87.02		fence	fence
162	2.1	6	65.45	100.00	82.73		fence	fence
163	2.2	6	61.60	100.00	80.80		fence	fence
164	2.3	6	51.76	100.00	75.88		fence	fence
165	2.4	6	49.64	100.00	74.82			

166	2.5	6	53.16	33.33	43.25			
167	2.6	6	24.39	33.33	28.86			
168	2.7	6	20.86	33.33	27.10			
169	2.8	6	19.81	33.33	26.57			
170	2.9	6	17.54	33.33	25.44			
171	3.0	6	23.86	33.33	28.60			
172	3.1	6	25.45	33.33	29.39			
173	3.2	6	28.97	33.33	31.15			
174	3.3	6	34.42	66.67	50.54		fence	fence
175	3.4	6	34.61	66.67	50.64		fence	fence
176	3.5	6	35.14	66.67	50.90	Underpass	fence	fence
177	3.6	6	28.49	66.67	47.58		fence	fence
1	3.7	6	31.48	33.33	32.40	Underpass		
2	3.8	6	33.94	33.33	33.64			
3	3.9	6	33.41	66.67	50.04		fence	fence
4	4.0	6	32.88	66.67	49.77	Underpass	fence	fence
5	4.1	6	26.03	66.67	46.35		fence	fence
6	4.2	6	23.57	66.67	45.12	Underpass	fence	fence
7	4.3	6	20.05	66.67	43.36		fence	fence
8	4.4	6	17.06	33.33	25.20			
9	4.5	6	22.32	33.33	27.83			
10	4.6	6	21.79	33.33	27.56			
11	4.7	6	21.26	33.33	27.30			
12	4.8	6	18.27	33.33	25.80			
13	4.9	6	13.35	33.33	23.34			
14	5.0	6	13.35	33.33	23.34			
15	5.1	6	12.82	0.00	6.41			
16	5.2	6	12.82	0.00	6.41			
17	5.3	6	12.29	0.00	6.15			
18	5.4	6	12.29	33.33	22.81			
19	5.5	6	14.94	0.00	7.47			
20	5.6	6	8.63	0.00	4.31			
21	5.7	6	10.56	0.00	5.28			
22	5.8	6	12.48	0.00	6.24			
23	5.9	6	12.48	0.00	6.24			
24	6.0	6	15.47	0.00	7.74			
25	6.1	6	16.00	33.33	24.67			
26	6.2	6	21.45	33.33	27.39			
27	6.3	6	21.98	33.33	27.66			
28	6.4	6	22.51	33.33	27.92			
29	6.5	6	24.62	33.33	28.98			

30	6.6	6	20.05	33.33	26.69			
31	6.7	6	20.05	33.33	26.69			
32	6.8	6	18.12	33.33	25.72			
33	6.9	6	13.73	33.33	23.53			
34	7.0	6	14.79	33.33	24.06			
35	7.1	6	12.33	33.33	22.83			
36	7.2	6	11.80	33.33	22.57			
37	7.3	6	6.35	33.33	19.84			
38	7.4	6	6.35	33.33	19.84			
39	7.5	6	9.15	33.33	21.24			
40	7.6	6	7.03	33.33	20.18			
41	7.7	6	7.90	33.33	20.62			
42	7.8	6	7.37	33.33	20.35			
43	7.9	6	7.37	33.33	20.35			
44	8.0	6	9.30	33.33	21.32			
45	8.1	6	8.24	33.33	20.79			
46	8.2	6	10.70	33.33	22.02			
47	8.3	6	10.70	33.33	22.02			
48	8.4	6	10.70	33.33	22.02			
49	8.5	6	15.08	33.33	24.21			
50	8.6	6	16.68	33.33	25.01			
51	8.7	6	16.68	33.33	25.01			
52	8.8	6	15.28	33.33	24.31			
53	8.9	6	15.28	33.33	24.31			
54	9.0	6	15.81	33.33	24.57			
55	9.1	6	13.88	33.33	23.61			
56	9.2	6	13.88	33.33	23.61			
57	9.3	6	10.89	33.33	22.11			
58	9.4	6	10.89	33.33	22.11			
59	9.5	6	13.88	33.33	23.61			
60	9.6	6	8.97	33.33	21.15			
61	9.7	6	4.04	33.33	18.69			
62	9.8	6	4.04	33.33	18.69			
63	9.9	6	4.04	33.33	18.69			
64	10.0	6	5.44	33.33	19.39			
65	10.1	6	4.38	33.33	18.86			
66	10.2	6	4.38	33.33	18.86			
67	10.3	6	5.44	33.33	19.39			
68	10.4	6	5.44	33.33	19.39			
69	10.5	6	5.97	33.33	19.65			
70	10.6	6	2.99	33.33	18.16			

71	10.7	6	2.99	33.33	18.16			
72	10.8	6	2.99	33.33	18.16			
73	10.9	6	2.99	33.33	18.16			
74	11.0	6	4.57	33.33	18.95			
75	11.1	6	3.18	33.33	18.25			
76	11.2	6	3.18	33.33	18.25			
77	11.3	6	3.70	33.33	18.52			
78	11.4	6	2.65	33.33	17.99			
79	11.5	6	11.27	33.33	22.30			
80	11.6	6	10.74	33.33	22.04			
81	11.7	6	10.74	33.33	22.04			
82	11.8	6	10.74	33.33	22.04			
83	11.9	6	10.74	33.33	22.04			
84	12.0	6	10.74	33.33	22.04			
85	12.1	6	9.15	33.33	21.24			
86	12.2	6	9.15	33.33	21.24			
87	12.3	6	9.15	33.33	21.24			
88	12.4	6	8.63	33.33	20.98			
89	12.5	6	14.26	33.33	23.80			
90	12.6	6	5.64	33.33	19.48			
91	12.7	6	5.64	33.33	19.48			
92	12.8	6	5.64	33.33	19.48			
93	12.9	6	5.64	33.33	19.48			
94	13.0	6	8.10	33.33	20.71			
95	13.1	6	15.13	33.33	24.23			
96	13.2	6	16.19	33.33	24.76			
97	13.3	6	22.70	33.33	28.02			
98	13.4	6	24.28	33.33	28.81			
99	13.5	6	29.39	33.33	31.36			
100	13.6	6	23.76	33.33	28.54			
101	13.7	6	24.28	33.33	28.81			
102	13.8	6	25.34	33.33	29.34			
103	13.9	6	27.80	33.33	30.57			
104	14.0	6	28.86	33.33	31.10			
105	14.1	6	26.40	33.33	29.87			
106	14.2	6	24.29	33.33	28.81			
107	14.3	6	25.69	33.33	29.51			
108	14.4	6	22.17	33.33	27.75			
109	14.5	6	34.66	33.33	34.00		Fence	Fence
110	14.6	6	32.01	33.33	32.67		Fence	Fence
111	14.7	6	36.93	33.33	35.13		Fence	Fence

112	14.8	6	38.86	33.33	36.10		Fence	Fence
113	14.9	6	37.81	33.33	35.57		Fence	Fence
114	15.0	6	38.33	33.33	35.83	At-grade crossing	Fence	Fence
115	15.1	6	42.73	33.33	38.03		Fence	Fence
116	15.2	6	45.72	33.33	39.52		Fence	Fence
117	15.3	6	43.78	33.33	38.56		Fence	Fence
118	15.4	6	45.37	33.33	39.35		Fence	Fence
119	15.5	6	65.96	33.33	49.64		Fence	Fence
120	15.6	6	52.41	33.33	42.87		Fence	Fence
121	15.7	6	52.94	33.33	43.14		Fence	Fence
122	15.8	6	50.48	33.33	41.91		Fence	Fence
123	15.9	6	48.55	33.33	40.94		Fence	Fence
124	16.0	6	54.18	33.33	43.76	At-grade crossing	Fence	Fence
125	16.1	6	58.58	33.33	45.95		Fence	Fence
126	16.2	6	53.65	33.33	43.49		Fence	Fence
127	16.3	6	50.67	33.33	42.00		Fence	Fence
128	16.4	6	50.14	33.33	41.73		Fence	Fence
129	16.5	6	61.75	33.33	47.54		Fence	Fence
130	16.6	6	38.18	33.33	35.76		Fence	Fence
131	16.7	6	40.11	33.33	36.72		Fence	Fence
132	16.8	6	37.65	33.33	35.49		Fence	Fence
133	16.9	6	38.71	33.33	36.02		Fence	Fence
134	17.0	6	38.18	33.33	35.76	At-grade crossing	Fence	Fence
135	17.1	6	35.80	33.33	34.56		Fence	Fence
136	17.2	6	30.75	33.33	32.04		Fence	Fence
137	17.3	6	33.87	33.33	33.60		Fence	Fence
138	17.4	6	34.84	33.33	34.09		Fence	Fence
139	17.5	6	40.65	33.33	36.99		Fence	Fence
50	0.0	7	58.34	66.67	62.50		fence	fence
51	0.1	7	50.01	66.67	58.34	Underpass	fence	fence
52	0.2	7	60.20	66.67	63.43		fence	fence
53	0.3	7	62.53	33.33	47.93		fence	fence
54	0.4	7	64.40	33.33	48.87			
55	0.5	7	64.52	33.33	48.93			
56	0.6	7	71.90	33.33	52.62			
57	0.7	7	71.90	33.33	52.62			
58	0.8	7	71.37	33.33	52.35			
59	0.9	7	63.46	33.33	48.40			
60	1.0	7	62.93	33.33	48.13			
61	1.1	7	52.57	33.33	42.95			
62	1.2	7	55.03	33.33	44.18			

63	1.3	7	43.07	33.33	38.20			
64	1.4	7	37.09	33.33	35.21			
65	1.5	7	41.14	33.33	37.23			
66	1.6	7	35.69	33.33	34.51			
67	1.7	7	28.30	33.33	30.82			
68	1.8	7	29.71	33.33	31.52			
69	1.9	7	32.17	33.33	32.75			
70	2.0	7	32.17	33.33	32.75			
71	2.1	7	24.79	33.33	29.06			
72	2.2	7	24.26	33.33	28.79			
73	2.3	7	22.33	33.33	27.83			
74	2.4	7	25.31	33.33	29.32			
75	2.5	7	28.49	33.33	30.91			
76	2.6	7	17.06	33.33	25.20			
77	2.7	7	16.54	33.33	24.93			
1	2.8	7	16.01	66.67	41.34			
2	2.9	7	14.94	66.67	40.81			
3	3.0	7	14.60	66.67	40.63			
4	3.1	7	15.13	66.67	40.90			
5	3.2	7	15.66	66.67	41.16			
6	3.3	7	16.19	66.67	41.43			
7	3.4	7	18.46	66.67	42.56			
8	3.5	7	19.85	66.67	43.26			
9	3.6	7	20.00	66.67	43.33			
10	3.7	7	20.00	66.67	43.33			
11	3.8	7	20.00	66.67	43.33			
12	3.9	7	20.00	66.67	43.33			
13	4.0	7	20.00	66.67	43.33			
14	4.1	7	20.87	66.67	43.77			
15	4.2	7	19.81	66.67	43.24			
16	4.3	7	24.20	66.67	45.43			
17	4.4	7	25.07	66.67	45.87			
18	4.5	7	28.58	66.67	47.63			
19	4.6	7	24.20	66.67	45.43			
20	4.7	7	20.87	66.67	43.77			
21	4.8	7	20.87	66.67	43.77			
22	4.9	7	20.87	33.33	27.10			
23	5.0	7	26.13	33.33	29.73			
24	5.1	7	22.27	0.00	11.14			
25	5.2	7	19.28	0.00	9.64			
26	5.3	7	20.68	0.00	10.34			

27	5.4	7	15.76	0.00	7.88			
28	5.5	7	20.49	0.00	10.24			
29	5.6	7	16.64	0.00	8.32			
30	5.7	7	18.04	0.00	9.02			
31	5.8	7	16.64	0.00	8.32			
32	5.9	7	16.64	0.00	8.32			
33	6.0	7	17.17	0.00	8.58			
34	6.1	7	13.31	0.00	6.65			
35	6.2	7	15.77	0.00	7.88			
36	6.3	7	15.77	0.00	7.88			
37	6.4	7	14.37	0.00	7.18			
38	6.5	7	17.70	0.00	8.85			
39	6.6	7	11.57	0.00	5.79			
40	6.7	7	9.11	0.00	4.56			
41	6.8	7	7.71	0.00	3.86			
42	6.9	7	9.11	0.00	4.56			
43	7.0	7	9.11	0.00	4.56			
44	7.1	7	8.58	0.00	4.29			
45	7.2	7	7.18	0.00	3.59			
46	7.3	7	5.20	0.00	2.60			
47	7.4	7	5.77	0.00	2.89			
48	7.5	7	6.50	0.00	3.25			
49	7.6	7	7.42	0.00	3.71			
0	7.7	7	2.56	0.00	1.28			

21. APPENDIX J: PUBLIC MEETING FEEDBACK

Poster/Road section	**Comments**	**Responses research team**
Stream Crossings Teton County		
	Are Fall Creek Rd crossings adequate for fish passage?	Yes
Traffic Volume/speed		
Section 3, Hwy 89	Please lower speed limit south of Y to town's 25 mph zone. Cars go much faster than 35	The research team suggests additional street lights (sensitive to the dark skies initiative) along the highway adjacent to High School Butte and at Broadway (except for the immediate vicinity of the suggested overpass).
Section 4, Hwy 89, Broadway	Why are sagebrush Apts. allowed?	This is for the permitting entities to answer.
Section 4, Hwy 89, Broadway	Should demand environmental studies in town	This is for the permitting entities to answer.
Section 4, Hwy 89	Please consider stretch of road N of town before N Park boundary for an overpass	The research team suggests an overpass between N end of east Gros Ventre Butte and the Gros Ventre River
Section 6, Hwy 22	Lower speed limit on 22, please	The traffic volume on Hwy 22 is so high that it is close to an absolute barrier to wildlife during most hours of the day. The research team suggests a combination of barriers (fences, barrier walls) and underpasses and overpasses to reduce collisions and to provide safe wildlife passages that are physically separated from traffic.
	Also reduced night speed	See above

Section 6, Hwy 22	Reduce speed limit on Hwy 22, between Science School & Snake River 55 MPH does not allow wildlife to cross or residents to enter highway	See above. Note: while safe access to and from highways is important, it is not addressed for this particular project.
Alta	North-South migration corridor in Alta missing from study	Correct. This is because, due to budget constraints, the large mammal part of the project was restricted to the major highways only.
Alta	Ski Hill Rd missing from study	Correct. This is because, due to budget constraints, the large mammal part of the project was restricted to the major highways only.
Large mammal-vehicle collisions		
Section 6, Bar Y	I recently witnessed a moose and calf run all the way down Bar Y estates and cross Hwy 22 midday, then continued to the land owned by the Science School. It was a miracle that they did not get hit by the constant traffic on Hwy 22. I know moose have gotten hit all along Hwy 22. This is critical and address sooner rather than later. Valerie Conger.	This section is known to be a problem with elk and moose collisions. It is also known to be important to elk and moose movements. The research team suggests a wildlife overpass at this location.
Section 6, Hwy 22, Bar Y entrance	Multiple moose kills - multiple elk & deer kills in 2016-2017. +1 (second person agreed)	The data show a concentration of elk hits and that this is an important movement area for elk. In addition, multiple people have commented on moose movements and moose hits in this road section. The research team suggests wildlife fences and an overpass at the ridge at the Bar Y
Section 6, Hwy 22, mile marker 15-16	Many moose seen crossing road. Wetland/creek all along Hwy, Moose seen XC. Kim Trotter. Also many deer licking salt/eating grass along Hwy to ID state line.	The collision data indeed show a concentration of moose hits in this road section. The research team has formulated additional mitigation for moose along this road section (Hwy 22, mi marker 15-16).
Section 7, Hwy 390	I don't believe any elk killed in section with signs and reduced night speeds	No elk-vehicle collisions hotspots were identified along Hwy 390
Alta, Ski Hill Road	(On ID side in Teton County) also has dead volume deer on road. Kim Trotter	Due to budget constraints, the large mammal part of the project was restricted to the major highways only.

Wildlife movements		
Section 6, Hwy 22	Elk herd crosses Spring Gulch Rd near road up to Spring Creek - that road will be more and more heavily traveled as time goes by -	Spring Gulch Rd was not part of the large mammal part of the project. This is because, due to budget constraints, the was restricted to the major highways only.
Alta	Large mammal migration corridors in Alta are missing from study	Correct. This is because, due to budget constraints, the large mammal part of the project was restricted to the major highways only.
General	Use animal detection systems in all high impact zones while we develop actual crossings. Valerie Conger.	Animal detection systems can, in general, be implemented more rapidly than underpasses or overpasses. However, be careful as animal detection systems are not appropriate for high volume roads (e.g. above 10,000-15,000 vehicles per day as sudden braking can result in rear-end collisions.
General	Speed limit reductions at dusk. Elizabeth Hale.	It is a problem (i.e. dangerous) if the posted speed limit is substantially lower than the design speed, and vehicle operating speed should be – at a maximum – around 35-40 MPH to have a reasonable chance of avoiding night-time wildlife collisions.
General	Wildlife don't tend to just randomly roam, although it may seem so to some. Most often they move locations to meet food, water, mating, and paturation demands. Some display seasonal behavior and thus seasonal approaches should be considered. Some display nocturnal behavior. Identification of territories such as elk feed grounds that draw animals and the relocation of those feed grounds to direct the behavior away from vehicle/animal interface would be useful. Linda J Cooper.	Indeed, while many wildlife species are wide roaming, their movements are not random. We recognized and identified migration corridors for large ungulates. We also recognize that most wildlife avoid highways during the day and cross more often when visibility is much reduced (at dusk, during the night, at dawn). Seasonal wildlife warning signs can have some effect on collision reduction, but the research team aims for mitigation measures that are more effective. Night time speed limit reduction to about 35 MPH is recommended, but only on roads that have a very low design speed to begin with. Feed grounds also influence where and when animals move, specifically elk. However, the assessment of the influence of feed grounds and potential recommendation of changing the location of feed grounds or recommendations to eliminate feed grounds altogether are outside the scope of this project.

General	Wyoming Game and Fish Department is not exclusively, but in a major way, driven by hunting license requirements. Their metrics include the size of herds and where they are located relative to species specific licensing districts. Re-examination of the hunting districts for the species of concern which now include iconic species may be useful. Also some wildlife require larger areas than others. This wildlife mapping is as important as where local residents see specific animals. Linda J Cooper.	While the research team recognizes the influence of hunting regulations, evaluating hunting regulations is outside of the scope of this project. The research team recognizes the importance of citizen science and has used citizen science data for this project.
General	Identification of predator/prey species and other food driven issues may also impact where interventions are located. For example, areas where mule deer locate is a prime area for cougar. An area where elk congregate is where wolves prey. An area where water and willows are predominate moose locate. I have personally seen cougar crossing 191. I have seen live and dead fox on 191. I have seen live and dead possum on 191. Linda J Cooper.	Indeed, prey and predator species influence each other's spatial movements.
General	Identification of the locations of evening trips to specific water locations before ungulates bed down for the nite would provide locations where the vehicle / animal interface might require intervention. Linda J Cooper.	Indeed, human presence and disturbance influences wildlife movements. However, evaluation of human presence and activity, specifically boat launch and take-out sites are outside of the scope of this project.
General	Seasonal migration of pronghorns and mule deer, and the seasonal movements of elk to the high country or the feed ground are well known and for these patterns the most direct interventions should be used.	The research team used available data on seasonal migration corridors for large ungulates. These areas are marked as important areas and where connectivity across highways should be improved rather than diminished.
Draft suggestions mitigation measures		
Section 1, Hwy 191, Hoback Jct - Camp Creek	Where would power for signs/lights come from? Solar?	Solar is possible. However, should a power drop from the grid be available, then that would also be a possibility.
Section 1, Hwy 191, Hoback Jct - Camp Creek	Not sure about the Camp Creek idea. Please add an underpass or overpass. This almost seems like an invitation for target practice in terms of animal-vehicle collisions – People do not generally slow their speed down to 35 MPH just because there is a sign. The lighting helps, but still – if you are going through the trouble of installing fences, please go the extra mile and add an underpass or overpass. Valerie Conger.	Physical separation of traffic and wildlife is better, especially regarding also mitigating the barrier effect of roads and traffic. However, IF at-grade crossings are considered, they should be on low-volume roads such as in this road section. But the research team agrees that connectivity problems are better addressed through underpasses and overpasses than through at-grade crossings.

Section 1, Hwy 191, Hoback Jct - Camp Creek	Regarding fencing I do not believe fencing is necessarily appropriate on 191. Directing elk via food sourcing relocation might be considered. Regarding bighorn sheep often on the road licking mineral salt or grazing on the sides it would seem obvious, eliminate the food source. Linda J. Cooper.	While the research team acknowledges the influence of feed grounds on elk location and movements, the evaluation of feed ground policy and feed ground location is outside the scope of this project. Road salt is often mixed in with sand to reduce clumping of sand rather than as de-icers. The research team recognizes the attraction of road salt though and will suggest exploring alternative anti-clumping or de-icers.
Section 2, Hwy 89/26, Cabin Creek	Not sure I understand Cabin Creek concept. Is this an underpass? Do animals have to walk through water?	Apologies for the confusion. This structure is not for terrestrial mammals. It only deals with aquatic concerns, especially erosion, water velocity etc.
Section 3, Hwy 89, Game Creek-Evans Trailer Park	Lower night time speed limit between Game Creek + Evans Trailer Park. (It could even start at the Trash Transfer Station). We live right above the Snake River where it makes its turn from west to south. We watch the animals cross the highway trying to get to their water source, the Snake. Francesca Hammer.	It is a problem if the posted speed limit is substantially lower than the design speed, and vehicle operating speed should be – at a maximum – around 35-40 MPH to have a reasonable chance of avoiding night-time wildlife collisions.
Section 3, Rafter J	Use overhead lamps – or motion detection lamps – to light stretches of road where animal collisions happen frequently (e.g. Hwy 390 near R Path/Hwy 390/Hwy 22 junction area) + highway near Rafter J, especially while we wait for crossings to happen. Valerie Conger.	In general, lights can discourage large mammals from approaching and crossing a highway. So, lighting alone is likely to increase the barrier effect for wildlife. Only consider lights if connectivity is not a concern, or if a safe and effective crossing opportunity is provided nearby.
Section 3, Overpass south of Jackson (about mi 150.8)	Eliminate crossing at mm 151 on So Hwy 89/191. Continue the exclusion fence to move animals North or South as been started by WYDOT. Wyo Game & Fish does not support this crossing. It places animals where they can not manage them & they do not want them west of the highway.	This is a comment from a citizen, not by WY G&FD. Note that fences alone make highways into impermeable barriers that fragment wildlife populations and that prevent wildlife from having access to vital resources. In this particular case mule deer winter habitat would be jeopardized as they use both sides of the highway. The west side may be critical for water and/or thermal cover and/or food. In addition, fences alone would block some mule deer on their migration path on the west side of the highway between this location and High School Butte. Finally, the structure is not physically connected to private lands (see next comment).

Section 3, Overpass south of Jackson (about mi 150.8)	It is linked to address the movement and collision rates between Melody /South Park Loop Road and Smiths. Along with the impediment above is resolving that the west landing onto the ranch lands will remain undeveloped so the investment in a crossing is not diminished by wildlife no longer be able to move through what has become dense development.	This location is north of the high-density development of the Rafter J. The site is located next to County, Wyoming Wetland Society and US Forest Service lands
Section 3, Overpass south of Jackson (about mi 150.8)	Not sure closing the overpass to Lockhart land is a good idea. Would it confuse/discourage wildlife? Valerie Conger.	The research team agrees that temporary closure of a crossing structure to all or selected species is not ideal. It could also lead to reduced use during time periods when the structure is open to wildlife. The research team only mentioned potential temporary or species-specific barriers to address potential human – wildlife conflicts, especially regarding potential disease transmission from elk to cattle.
Section 3/4, High School Rd - Town	Speed limit reduction - Smith's to Town's 25 MPH zone. Elizabeth Hale.	This depends on WYDOT's policy. But be careful, because while such low speed limit may be viable and justified during high traffic volume hours, the design speed of this road section is much higher. Therefore, drivers are unlikely to adhere to very low speed limits during low traffic (i.e. at night when collision risk is highest).
Section 4, Hwy 89, Broadway	The plan for Broadway should be implemented ASAP. Valerie Conger.	
Section 4, Hwy 89, N Jackson - N end of East Gros Ventre Butte	Consider additional crossings from Fish Hatchery Hill to the town of Jackson. This stretch has fencing and prevents connectivity. Bighorn sheep and mule deer would be afforded connectivity and access to additional crucial winter range. You have public -> public parcels of NER ands and access permanent conservation easement.	The research team agrees and has formulated suggestions for additional safe crossing opportunities.
Section 4, Hwy 89, N Jackson	What about N of Jackson? I did not see any concepts on the boards for this area. There is an abundance of wildlife crossing the entire stretch N of town all the way to Buffalo Valley Rd and beyond. Please consider these areas too. Valerie Conger.	Based on this comment and the comment above, the research team has formulated additional suggestions for the road section between the north end of Jackson and the northern end of Gros Ventre Butte. However, the road section between the Gros Ventre Bridge and 2 mi east of Moran Jct is through the Park and outside of the boundaries for this project. The road section through Buffalo Valley is part

		of the project though. Buffalo Valley is important for elk and moose movements. However, no mitigation measures are formulated for road section 5 (Moran Jct – Togwotee Pass) as this road section was recently mitigated, at least locally.
Section 4, Hwy 89, N of airport -> Buffalo Valley rd	Please use data collected to determine the points of highest collision activity and select the most useful areas for underpasses/overpasses.	This part of Hwy 89 is through the National Park and falls outside of the boundaries for this project.
Section 5, Hwy 287, Buffalo Valley	What about N of Jackson? I did not see any concepts on the boards for this area. There is an abundance of wildlife crossing the entire stretch N of town all the way to Buffalo Valley Rd and beyond. Please consider these areas too. Valerie Conger.	Based on this comment and the comment above, the research team has formulated additional suggestions for the road section between the north end of Jackson and the northern end of Gros Ventre Butte. However, the road section between the Gros Ventre Bridge and 2 mi east of Moran Jct is through the Park and outside of the boundaries for this project. The road section through Buffalo Valley is part of the project though. Buffalo Valley is important for elk and moose movements. However, no mitigation measures are formulated for road section 5 (Moran Jct – Togwotee Pass) as this road section was recently mitigated, at least locally.
Section 6, Hwy 22	Speed limit reduction on 22. Elizabeth Hale.	This depends on WYDOT's policy. But be careful, because while such low speed limit may be viable and justified during high traffic volume hours, the design speed of this road section is much higher. Therefore, drivers are unlikely to adhere to very low speed limits during low traffic (i.e. at night when collision risk is highest). In addition, the traffic volume on Hwy 22 is so high that it is a very substantial barrier to wildlife and lower speeds do not lead to lower traffic volume and the barrier effect is likely to remain very high.
Section 6, Hwy 22, Vogel Hill	Vogel Hill overpass should be a top priority due to impending Tribal Trails Rd.	The research team agrees that connectivity in this area is vital for both mule deer migration and elk movements.

Section 6, Hwy 22, Bar Y / Sky line Ranch overpass	Landowners at Hwy 22 Northside at Bar Y will grant an easement for an overpass structure at the draw just east of Bar Y entrance. Let's make this happen soon - not 10-20 years from now. Gail Jensen. +1 +1 (note Marcel Huijser: comment was supported by 2 others)	The research team will let Teton County and NGOs involved with wildlife connectivity know about this opportunity.
Section 6, Hwy 22, near Idaho border/Coal Creek/Mail Cabin Creek	Yes! Absolutely! Kim Trotter	The research team has formulated additional mitigation for moose along this road section (Hwy 22, mi marker 15-16).
Section 7, Jct Hwy 390/Hwy 22	Use overhead lamps – or motion detection lamps – to light stretches of road where animal collisions happen frequently (e.g. Hwy 390 near R Path/Hwy 390/Hwy 22 junction area) + highway near Rafter J, especially while we wait for crossings to happen. Valerie Conger.	In general, lights can discourage large mammals from approaching and crossing a highway. So, lighting alone is likely to increase the barrier effect for wildlife. Only consider lights if connectivity is not a concern, or if a safe and effective crossing opportunity is provided nearby.
Section 7, Hwy 390	Current signs and reduced night speeds have reduced moose deaths from 8-9/yr to 0-1. SIGNS WORK!!	Wildlife warning signs can reduce collisions with large mammals if they are location and time specific. Reduced speed limit cannot be much below the design speed of a highway as that would result in a speed dispersion (mix of slow and fast-moving vehicles) and this is associated with an increase in crashes and reduced human safety. In order to have a chance at stopping in time for a large mammal on the road at night, the operating speed of vehicles with average head lights should be around 35-40 MPH at a maximum. Therefore, reduced speed limits can only be considered along highways that have a very low design speed and low associated posted speed limit already. It is not a solution for major highways with high design speed (e.g. 65 MPH) unless the design speed of major highways is substantially reduced. The latter would be in direct conflict with the main mission of transportation agencies to provide safe and efficient transportation. However, for a portion of Hwy 390, the existing reduced night time speed limit (35 MPH) is a measure that can be effective. The research team suggests the continuation of this measure along this road section.

Section 7, Hwy 390	In relation to comment above: what has moose population done in same time period?	The research team will analyze moose-vehicle collision data on Hwy 390 to investigate the potential effects of the existing mitigation measures.
Section 7, Hwy 390 near Hwy 22	Stretch of 390 near 22 – xxx mile or so when 11 moose were killed a few years ago. Reduced speed has actually helped but I wrote WYDOT and suggested that overhead motion detection lights be added in this stretch. Valerie Conger.	In general, lights can discourage large mammals from approaching and crossing a highway. So, lighting alone is likely to increase the barrier effect for wildlife. Only consider lights if connectivity is not a concern, or if a safe and effective crossing opportunity is provided nearby.
Section 7, Hwy 390 near Hwy 22	More slow speed signs that use the red/white/blue lights when speed limits are exceeded placed in key collision areas. Valerie Conger.	This can be helpful to encourage people to adhere to the posted speed limit. However, it is a problem if the posted speed limit is substantially lower than the design speed, and vehicle operating speed should be – at a maximum – around 35-40 MPH to have a reasonable chance of avoiding night-time wildlife collisions.