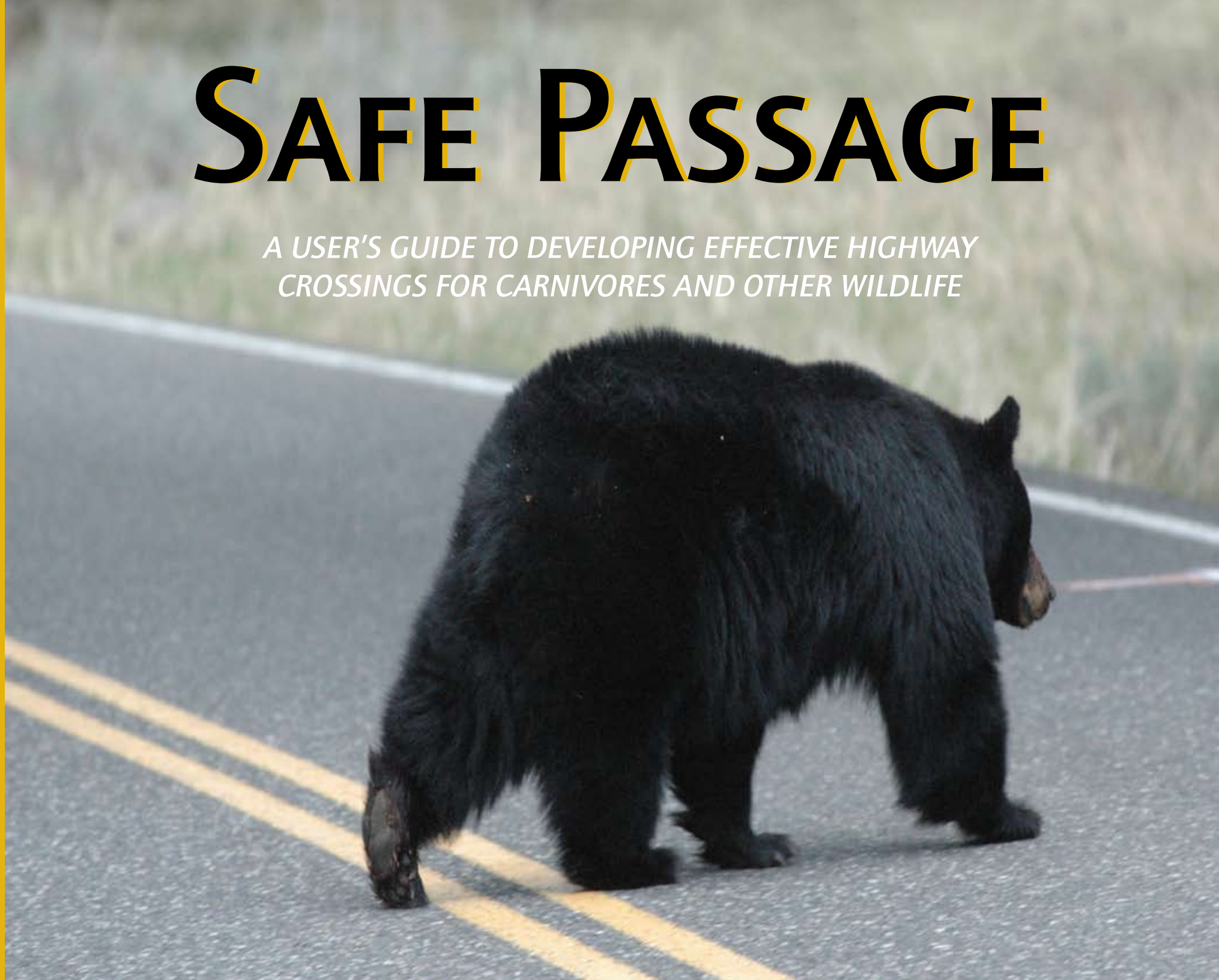
Safe Passage

A User's Guide to Developing Effective Highway Crossings for Carnivores and Other Wildlife



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Front Cover Photograph ©Jim Robertson: Black Bear in Yellowstone; Back Cover Photograph ©Roy V. Rea: Coyote on Highway 16 near Jasper, AB in Jasper National Park.

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TABLE OF CONTENTS

Introduction 4

Building Relationships 5

Wildlife Habitat Linkages 6

Tools for Connectivity Planning 6
- *Aerial Photos* 6
- *Land Ownership Maps* 6
- *Vegetation Maps* 6
- *Topography* 7
- *Wildlife Habitat and Range* 7
- *Roadkill Information* 7
- *Initiating a Connectivity Plan* 8

Types of Wildlife Crossings 8
- *Signs* 8
- *Interactive Signs* 9
- *Round Culverts* 9
- *Box Culverts* 9
- *Multi-Plate Arches* 10
- *Open-Span Bridges* 10
- *Bridge Extensions* 10
- *Wildlife Overpasses* 11

Designing an Effective Wildlife Crossing 12
- *Keep it Natural* 12
- *Location* 12
- *Approaches* 12
- *Crossing Bottom Material and Design* 13
- *Fencing* 13
- *Escape Ramps* 14
- *Lane Configuration* 14
- *Highway Bridge Heights* 14
- *Structure Size and Type* 15
- *Species-Specific Considerations* 15
  - *Large Carnivores* 15
  - *Mid-Sized Carnivores* 16
  - *Small Carnivores* 16
  - *Wildlife Crossing Checklist* 16

Wildlife Monitoring 17

Going Forward Together 17

Species-Specific Table 18

Appendix 19

Literature Cited 19

Further Information 19

INTRODUCTION: WHY ARE WE CONCERNED?

Management of carnivores in the Western United States is an important conservation objective. Several carnivores, such as Canada lynx, grizzly bear, Mexican gray wolf, Northern Rocky Mountain wolf, jaguar, San Joaquin kit fox, and ocelot are listed under the Endangered Species Act. Others such as wolverine, American marten, swift fox, and fisher receive special status due to rarity or conservation concerns. Even relatively common carnivores such as black bear, mountain lion, bobcat, coyotes, and raccoons are of great interest and concern to the public.

Carnivore populations exhibit several traits that can render them particularly vulnerable to habitat fragmentation and highway impacts. Because of the their large home-range sizes, carnivores often have to cross one or more highways to fulfill their food or water requirements, find mates, or disperse into unoccupied habitats. Carnivore populations can be at risk when mortality rates rise because of their low population densities and reproductive rates.

Highways are one of several important components to consider when managing carnivores and other wildlife species. Highways often result in serious unintended impacts such as direct and indirect losses of habitat, habitat fragmentation, population fragmentation, and increased mortality of wildlife and humans. Over the last twenty years, highway departments, land management agencies and wildlife agencies have worked together to develop management practices that reduce impacts to carnivores and other wildlife species. Simultaneously, research is increasingly available to assist agencies and the public in understanding how to reduce the impacts highways have on wildlife. This research has been directly applied to improve highway safety and mitigation through wildlife habitat linkage analysis, development of effective wildlife and fish crossing structures, fencing, and land purchase or conservation easements, to protect important wildlife habitats.

Growing scientific research shows the importance of wildlife crossings and restoring wildlife habitat connectivity. In Banff National Park, a series of 22 underpasses and two overpasses, tied together with fencing, have decreased total roadkills by 80 percent. Monitoring has documented approximately 75,000 crossings of wildlife using these structures including wolf, grizzly bear, elk, lynx, mountain lion, and moose. It is also known that large, interconnected wildlife populations are more "viable" or "persistent" than isolated small populations (Noss et al 1996; Noss 1987; Noss and Harris 1986; Noss 1983). Reducing or minimizing mortality is important for many species, particularly those that are rare, have low fecundity, or exist in small populations. Carnivore populations often fit within these categories.

An important benefit of fencing and wildlife crossings is a reduction in animal-vehicle collisions with large carnivores and other species like elk, deer, and moose. Such mitigation measures are as important to human safety as they are to wildlife conservation. Collisions or near collisions with these large animals are serious highway safety hazards. Human deaths and injuries are common when vehicles collide with large wildlife, or swerve off roadways to avoid collisions. In many rural situations, collisions with large animals, particularly deer, are the most common cause of highway collisions. A recent study by the Western Transportation Institute calculated the average total costs associated with an animal-vehicle collision for three species: $7,890 for deer, $17,100 for elk, and $28,100 for moose (Huijser 2006).

On December 6, 2005 the Southwestern Carnivore Committee held a "Carnivores and Highways" conference to address these issues. Biologists, engineers, and conservationists came together to recommend a suite of best management practices for small, mid-sized, and large carnivores. Those recommendations are the basis for this document.

Safe Passage was written for engineers, biologists, and conservationists in the Western United States and Canada who are working in the field on a day-to-day basis to address the technical aspects of creating the most ecologically effective and economically efficient wildlife crossings structures. In the following pages, you will find practical information on tools for connectivity planning, types of wildlife crossings, and design guidelines for carnivores and other wildlife.

Black bear roadkill on I-70 near Vail, Colorado.

BUILDING RELATIONSHIPS: GOOD DECISIONS START WITH GOOD RELATIONSHIPS

Developing effective highway wildlife mitigation measures is an interdisciplinary and collaborative effort involving highway agencies, wildlife, and land management agencies, as well as concerned communities, including local governments and policy makers. Individuals from many different professions, often without much understanding of each other's disciplines, must work in concert to produce effective highway projects that are safe, cost effective, and mitigate ecological impacts. Communication problems can contribute to misunderstandings and trust issues, which are factors that may hamper progress and must be worked through to reach sound, defensible, common sense solutions.

Considerations for Biologists: Get to know your Forest Service, local and State Department of Transportation (DOT), and Federal Highway Administration (FHWA) engineers and environmental staff. Many engineers are not trained in ecological sciences, so it may be helpful to provide basic information on habitat connectivity, mortality impacts, and habitat loss before critical project decisions are made. Presentations at local and regional engineering meetings to communicate this information will also help. Informal meetings with highway project planners, engineers, and community leaders can establish a rapport and be beneficial to understanding issues for both parties. Often other professionals do not understand ecological issues that you may have studied for years. Gaining trust and credibility takes time and effort, and must be earned. Listen to what the concerns are and be willing to help planners and engineers address these issues. Engineers often have creative solutions to biological problems, so be open minded to their ideas.

Biologists should understand that a cost-efficient and effective wildlife mitigation program on a highway should be a negotiation process. If you do not have highway mitigation experience, contact a credible biologist that works on highway projects. Do this in consultation with the highway project manager and environmental staff from the State DOT. Remember that project and DOT managers are often very concerned with factors such as motorist safety, cost, and project delivery deadlines. Learn how to work within these parameters.

Considerations for Engineers: If your highway project is going across public lands or sensitive wildlife habitat, invite local biologists from a variety of agencies to discuss which species and ecological issues might be important. Explain the transportation planning process and the importance of timeliness when addressing concerns and issues so you can deliver your project on time and within budget. Remember, that most biologists know little about engineering, so you will need to explain these concepts as well. Most resource agencies find the state transportation planning process confusing and different than their process, so be patient. Often resource agencies do not expect to be involved until the NEPA alternatives are developed. This may be disastrously late for project engineers to learn about serious wildlife issues and conflicts.

Engineers, biologists, and conservationists at a wildlife crossing site visit on Vail Pass, I-70 in Colorado.

If wildlife connectivity issues are identified as a concern during planning or project scoping, State DOTs should build in funding for wildlife crossings and other ecological mitigation measures as part of the up-front cost estimate. Explain the importance of delivering a project on time – not only for the current project but to enhance the likelihood that future projects will consider similar wildlife mitigation measures. If a considerable amount of resource agency staff time is needed to assist in project development, the DOT should consider providing funding to the resource agency so they are not taking resources away from delivering their mission. Resource agencies are operating on minimal budgets and do not get funding to coordinate large, complex highway projects. Planning for mitigation measures from the outset will save money in the long run.

Other Partners: Conservation groups often play pivotal roles in identifying and planning wildlife habitat linkages. They have valuable expertise and can bring agencies together to work cooperatively. They may also be more effective in dealing with wildlife habitat linkages on private lands than agencies. Conservation groups are often key to gaining local support for highway projects and can work with concerned citizens and political leaders for project support and funding.

Training: Wildlife, land management, and transportation agencies usually have very different priorities and missions. Effective wildlife habitat linkage assessments and wildlife crossing implementation require agencies and different professionals to work as a team. Progress occurs when agencies pool information and achieve consensus, as quickly as possible, on the locations and types of wildlife crossings that are needed. Agencies should consider working together on training sessions that help key players share expertise and reach consensus quickly. Traffic safety, cost containment, and meeting deadlines should be part of this training as should habitat connectivity, wildlife mortality reduction, and structure design and effectiveness.

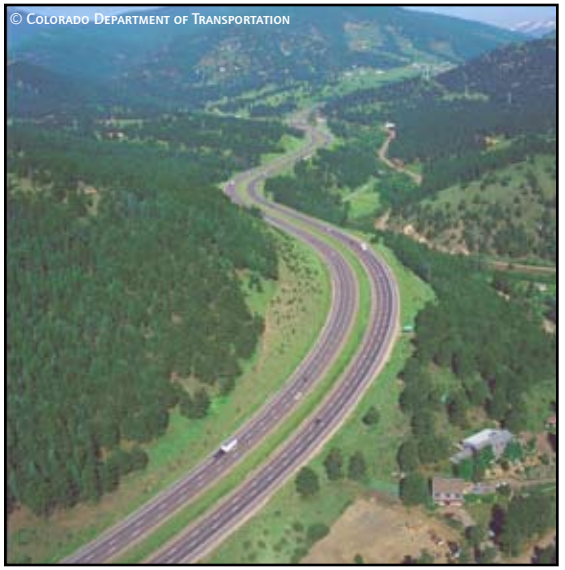
WILDLIFE HABITAT LINKAGES: DETERMINING WHERE WILDLIFE CROSSINGS ARE IMPORTANT

One of the primary purposes of developing habitat connectivity plans is to minimize the impacts of transportation infrastructure on public lands and other important habitats. Preparing statewide or regional plans for habitat connectivity (wildlife habitat linkages) is an essential part of developing a comprehensive system of effective wildlife crossing structures. Habitat fragmentation, habitat loss, and high mortality rates are often primary issues in conserving state wildlife resources. Wildlife and land management agencies that spend time working on wildlife habitat linkages, wildlife crossings, and other mitigation measures often maximize long-term benefits to future wildlife resources. Developing a statewide wildlife habitat connectivity plan can address many of these issues and benefit a diversity of wildlife species. Successful statewide wildlife habitat connectivity plans include Arizona, New Mexico, Colorado, and Utah (see pg. 19 for further information). Though ideally the best scale to start at is statewide, opportunities often exist on smaller scales such as a state DOT or wildlife agency regional boundary or an important highway segment. Regardless, connectivity plans should have the support of public land management agencies, wildlife agencies, and conservation groups.

In addition to the following tools, a connectivity plan should take into consideration the DOT's Statewide Transportation Improvement Program (STIP). The STIP is renewed every 1-3 years and covers the funded projects expected to happen over a 5 year period.

TOOLS FOR CONNECTIVITY PLANNING

1. Aerial Photos: Aerial photos are available in various scales and image formats such as black and white, color, color infrared, and ortho-photos. These can be used to identify vegetation patterns and types, housing and human developments, water bodies, aspect and terrain and many other important details. On quality images such as high resolution color infrared, game trails and paths may be evident.



Aerial photo of the I-70 corridor near Denver, Colorado.
(Photo is sole property of CDOT and should not be distributed for other usage)

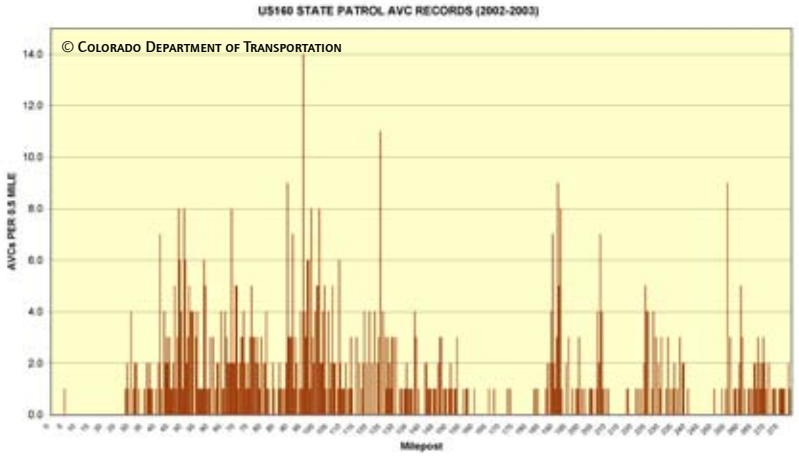
2. Land Ownership Maps: Adjacent land use management is critical to the success of wildlife crossings. Most public lands include wildlife habitat protection as one of their mandates or guiding principles. For this reason, identifying wildlife habitat linkages is much easier when public lands are involved. One of the primary benefits of wildlife habitat linkages is to minimize fragmentation of wildlife habitat on public lands. These may be county lands used for "open space," state wildlife management or natural resource lands, or a variety of lands managed by the Federal government. In some situations, identifying key parcels of private land may also be an important step in protecting wildlife linkages.

3. Vegetation Maps: Vegetation maps that include general vegetation types such as conifer or hardwoods, riparian or upland, marshes or grassland provide sufficient detail for wildlife habitat connectivity planning. The National Vegetation Land Classification is suitable for most small-scale work, such as statewide, regional, or highway corridor assessments. Most public land agencies have their own vegetation maps, which may provide more accurate and current information.

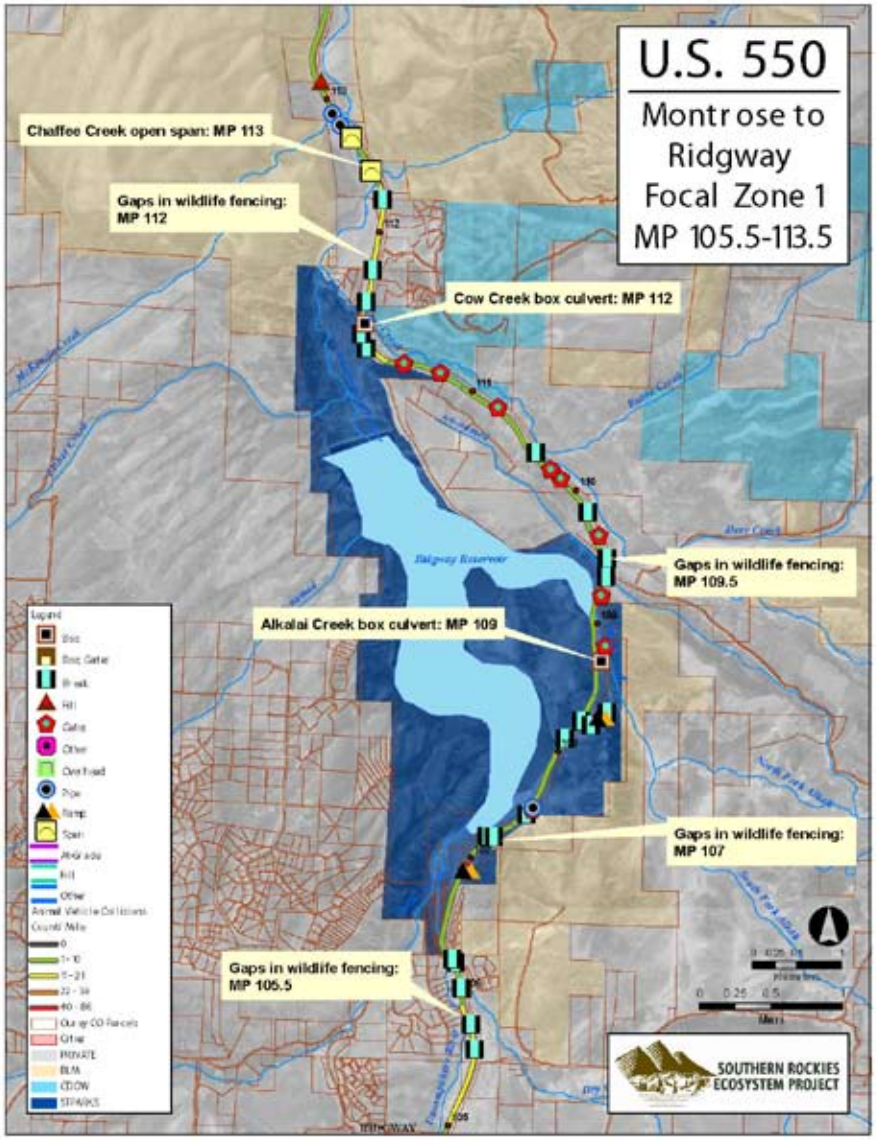
4. Topographic Maps: Topographic maps provide important information such as slopes, draws, ridges, saddles, extremely steep lands, flats, and can often be used to help identify wildlife corridors. Riparian habitats are usually discernable including lakes, ponds, marshes, bogs, arroyos, swamps, streams, and rivers. Even on relatively flat landscapes, topographic maps often provide important clues on where wildlife may interface with highways. Roads, highways and other human developments are also identified on most topographic maps.

5. Wildlife Habitat or Range Maps: Maps may vary in quality from "unavailable" to exceptionally accurate. They can always be augmented with information provided by biologists, foresters, landowners, and others that live or work in the area. Wildlife habitat and range information can come from a variety of agency and non-agency sources. Agency sources include state wildlife agencies, state heritage programs, US Fish and Wildlife Service, and a variety of land management agencies. Non-agency sources include groups like The Nature Conservancy, Southern Rockies Ecosystem Project, and Rocky Mountain Elk Foundation.

6. Roadkill Information: This information is available from many State DOTs providing the location and number of collisions, and often the species, sex, and age of wildlife involved. Romin and Bissonette (1996) recommend factoring in a 16-50% increase when estimating animal-vehicle collision levels from accident reports, which are often not filed if injuries or property damage is minor.



Animal-vehicle collisions along US Highway 160, Durango, Colorado.



Linking Colorado's Landscapes map identifying land status, highway engineering and structures, and animal-vehicle collisions within a high priority wildlife linkage.

Initiating a Wildlife Habitat Connectivity Plan

Leadership is a key factor in developing statewide or regional wildlife habitat connectivity plans, organizing initial connectivity meetings, and keeping agencies on-task early in the planning process. Leadership may come from a conservation group, wildlife agency, land management agency, or DOT. Initial connectivity plans can begin simply, with existing information, local knowledge and a few maps. Review existing interagency MOAs, charters, or work plans to identify specific roles, responsibilities, and activities for key players.

Lead agencies can also utilize a new policy in the Transportation Bill, SAFETEA-LU, to catalyze their efforts. Planning provisions in SAFETEA-LU now require the preparation of 20+ year plans to include consultation with state, tribal, and local agencies responsible for land use management, natural resources, and environmental protection. This could provide a good opportunity to start a connectivity plan in your state. Additionally, each state wildlife agency now has a State Wildlife Action Plan that should be utilized as much as possible. See http://www.teaming.com for more information on these wildlife plans. Plans are only worthwhile if you implement them.

If you have an interest in carnivore conservation or other wildlife in your state or region, or in developing better highways, why not step forward and organize a wildlife habitat connectivity meeting?

Canada lynx at a ski resort in Telluride, Colorado.

SELECTING AND DESIGNING EFFECTIVE WILDLIFE CROSSINGS

Once a plan is in place for wildlife habitat linkages, the next step is to take advantage of available highway crossing technology. The long-term objective should be to develop a systematic program of wildlife habitat linkages and appropriate wildlife crossings. Starting conservatively, with wildlife crossings that are modestly priced and monitoring their effectiveness, is likely to help DOTs develop experience and confidence that wildlife crossings can be an effective and cost-efficient way to improve highway safety. Each state has a variety of wildlife and highway issues, a variety of habitats, and different social values related to highways and wildlife. One size does not fit all! Be creative and flexible!

TYPES OF WILDLIFE CROSSINGS

Choosing the appropriate wildlife mitigation measures on a segment of highway is a complex decision. To be successful, you may need a variety of treatments.

The critical elements of wildlife crossings include target species, structure effectiveness, engineering constraints due to terrain, cost for construction, maintenance, improvements to highway safety, and aesthetics. The following is a summary of the more common types of wildlife crossings:

Signs: This category includes signs with deer or other animals commonly observed on highway rights-of-way. Signs alert motorists to be watchful of wildlife on the roadway, but have little or no impact on mortality rates, habitat connectivity, or human safety. Signs alone are not recommended as a mitigation measure for habitat fragmentation or wildlife mortality. The exception may be in National Parks or places where signs may be used in conjunction with slow traffic speeds. Cost of signing is minimal, which is why it is often utilized.

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Variable message sign on US Highway 550, north of Ridgway, Colorado.

Interactive Signs:

Interactive signs include new technology that incorporates signs that activate only when wildlife is present in highway rights-of-way. Interactive signs have the best potential on lower traffic volume roads, and only detect large animals. Maintenance is a consideration and the efficacy of interactive signs is still being tested. Applications are limited to low volume roads with large animals like deer, elk, mountain sheep, moose, mountain lion, or bears. Night-time speed reduction signs and variable message signs are being utilized in some states as an alternative means of impacting driver behavior rather than the traditional static signs. The cost of interactive signs is moderate.

Culverts:

Culverts are used extensively on highways for a variety of applications, mainly for moving water beneath roads. Round and elliptical culverts are used for small streams, intermittent streams, and for cross ditching. Material used for culverts may be metal, cement, or molded plastic. Of these, cement may be the best for crossing structures because it has some attributes of natural ground surfaces and maintains moisture. The application of culverts to wildlife passage primarily benefits small and mid-sized carnivores, up to and including coyotes and bobcats, during times of the year when there is little or no water present. Forty-eight inch culverts should be the minimum size if coyote or bobcat are target species. Fencing associated with 36" and 48" culverts can be an effective ways to move small and mid-sized carnivores across highways. The cost for culverts is relatively low compared to other crossing structure types.


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Coyote approaching an elliptical culvert on Wolf Creek Pass, US Highway 160, Colorado.


© Chris Haas, CALTRANS

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Box culvert on HWY 13 south of Craig, Colorado (above). Bobcat using a box culvert in Riverside, CA under CA 71 (left).

Box Culverts:

Box culverts may be superior to round culverts due to the larger interior space compared to similar sized round culverts or arches. Box culverts, depending on size, can be suitable for small, mid-sized, and large carnivores. Box culverts are used commonly on highways in the Southwestern United States to deal with flash floods, offering an opportunity to build or retrofit existing structures to provide wildlife passage for a variety of carnivores. Box culverts have been used successfully in a number of situations. In Florida, large 8'h X 25'w box culverts have been used successfully as highway crossings for Florida panther and black bear. The cost of box culverts is usually modest compared to open-span bridges, bridge extensions, or wildlife overpasses.

Multi-Plate Arches:

Multi-plate arches are made using steel curved plates or, occasionally, cement arches. The arches are usually transported to the site and assembled. Most multi-plate arches have been used for large carnivores such as black bear, mountain lion, and grizzly bear, as well as deer and elk. For black bear and mountain lions, as well as many other species, they are often as effective as more expensive crossings. Natural light transmission through multi-plate arches is less than open-span bridges or bridge extensions. Depending on which species are being targeted, this may or may not be of concern. Multi-plate arches are relatively modest in cost compared to other large wildlife crossing structures.

Multi-plate arch constructed in 1973 on US Highway 160 near Mancos, Colorado.

Open-Span Bridges:

Open-span bridges have some benefits and drawbacks. The effectiveness of open-span bridges has been shown to be high for most large wildlife including deer, elk, black bear, grizzly bear, mountain lion, wolves, and a variety of smaller species. Open-span bridges should be considered where wildlife habitat connectivity is a high priority and where species like grizzly bear and wolves are present. Open-span bridges are often used in major elk and deer migration routes. Due to the design of open-span bridges, they are often constructed over natural drainages as opposed to fill slopes or flat terrain. Successful examples of open-span bridges for wildlife crossings have been built in Banff National Park, Colorado, Montana, Idaho, and Arizona. In Banff National Park, engineers and biologists consider open-span wildlife crossings to be a good compromise between high wildlife use and cost. Cost, however, can be relatively high, running $1 million and more per structure.

Span bridge on I-70, Colorado (above). Mule Deer using one of the same span bridges on I-70 (right).

Bridge Extensions:

Bridge extensions are probably one of the most beneficial and easily incorporated wildlife crossing structures because they are required for hydrological purposes and wildlife often follow drainages for daily or seasonal movements. Bridge extensions span aquatic ecosystems benefitting stream processes, wetlands, flood protection as well as aquatic organisms. Bridge extensions provide one of the best types of wildlife crossings because they are usually "open" and provide high natural light transmission and minimal confinement. Many wildlife species, including carnivores of all sizes, readily utilize the habitat under bridges, as do species like elk, deer, moose, antelope, mountain sheep, and mountain goats. DOTs often have bridge replacement programs, providing opportunities to leverage wildlife crossings with bridge repair or replacement. Bridge extensions may be costly.

Mule deer crossing under a bridge extension on the Florida River on US Highway 160 near Durango, Colorado.

Wildlife Overpasses:

Wildlife overpasses, ecoducts, or bridges, are not appropriate everywhere, but they make sense especially when connectivity for multiple species is being considered and the terrain does not allow for an open-span bridge. Wildlife overpasses are often the most effective wildlife crossing and benefit the largest number of species. Species that may shun under the road crossings, like grizzly bear, antelope, and moose may accept well-placed wildlife overpasses. In Europe, wildlife overpasses are more common because of their efficacy for plant connectivity and invertebrates, as well as for their superior performance for a variety of vertebrate species. Examples of wildlife overpasses can be seen throughout Europe, in Banff National Park (Canada) and Utah (for mule deer). Wildlife overpasses are currently being considered in Montana, Colorado, Idaho, Utah, and Washington. Overpasses are a comprehensive solution with a relatively high cost.

Computer simulation of overpass planned for I-90, Washington.

Wildlife overpass on the Trans-Canada Highway, Banff National Park (above). Wolf pack, mountain lion, and grizzly bear using a wildlife overpass in Banff (Below).

DESIGNING EFFECTIVE WILDLIFE CROSSINGS

The following are design elements that should be considered when building wildlife crossings for carnivores and other wildlife species:

Keep It Natural:

The more naturally a wildlife crossing fits into the surrounding area, the more likely animals will use it. A natural appearance is created when the vegetation approaching a crossing structure is similar to that of adjacent habitat, or when a structure is designed with a natural bottom. A natural-appearing structure also includes a minimal amount of features that would either intimidate or obstruct wildlife such as livestock fencing, cement walkways, rip-rap, construction debris, unnecessary fill, signing, or poles. A natural appearance is particularly important for wary species like grizzly bears and wolves.

Video footage from the United States and Europe indicates a wide array of wildlife behavioral responses to highway crossings. When the appearance of wildlife crossings is unnatural, approaching animals will watch the crossing, sometimes for several hours. After watching the crossing, some animals will cross, some will not, some will run through, and some will run or walk partway through and return without crossing successfully. It may cost slightly more to make a crossing appear natural, but it is money well-spent.

Researchers at the AZ Game and Fish Department have shown that wildlife prefer the sloped, more natural underpass (right) to hard-edged walls (left) on State route 260.

Location:

The general location of wildlife crossings can be assessed from aerial photos. The precise location of each structure should be made after considerable field work has been done to determine the best location. In most situations, wildlife crossings should be located precisely where animals naturally approach a highway, or where they have historically done so. Often, animals choose areas to cross where there is a specific terrain feature, vegetation, or a reduction in the number of lanes. Ridges, valley bottoms, stream and river courses, and wooded corridors often are choice locations. Location of wildlife crossings is one of the critical factors in optimizing their use.

Approaches:

How an animal approaches wildlife crossings may be the deciding factor in whether or not wildlife use a structure. Approaches should include habitat factors like vegetation near or at the crossing entrance. Several animals have shown preferences for using a structure where the distance between cover is the shortest. For example, studies in Canada indicate wolverine moved long distances parallel to highways to find areas where distances across roads was minimal and vegetation was close to the right-of-way.

Vegetation: Vegetation provides many benefits for a wildlife crossing. It minimizes the distance animals must travel between habitats on both sides of the highway. It shields animals from light and noise. It also provides cover which is often important to animals that are feeling vulnerable. When rights-of-way are cleared for highways, vegetation should be left at locations where wildlife crossings are planned. Also, trees and shrubs should be planted in approaches and between lanes for divided highways.

Discord Elements: Discord elements in the approach area may reduce a wildlife crossing's effectiveness. Excess road-fill material should not be placed at wildlife crossings. Bright pieces of metal, boxes, or other construction material should be removed from the crossing structure and approaches. Farmers or ranchers should not store equipment, hay, or other unnatural material in or near wildlife crossings or approaches. Sediment fences make use by many species difficult or impossible. Rip-rap is difficult for many species to traverse, especially ungulates and amphibians.

Line of Sight: Animals approaching wildlife crossings should be able to see through the structure to suitable habitat on the opposite side of the highway. Road-cuts, steep drop-offs, and cliffs may dissuade animals from making a suc-

cessful crossing. Structures should be designed as flat and straight as terrain permits. Crossings with steep grades reduce the "openness" of structures and dog-legs prevent animals from seeing habitat on the opposite side of the highway.

Crossing Bottom Material and Design:

To the extent possible, the bottom of structures should have similar soil as would occur if the structure were not there. Often, wildlife crossing bottoms are made up of coarse material from road cuts, cement, or metal. For some species that are more adaptable like coyote, black bear, raccoon, and opossum, bottom material may not be a significant factor. But, for other species including deer, elk, moose and other ungulates, crossing bottom material is important.

Bridges can provide both stream crossings and wildlife crossings. It is preferable to maintain a natural stream bank and let wildlife choose where to make trails or cross within a structure. Hardened vertical walls on structures, such as those made of building blocks and cement, seem to be less desirable than those of natural fill material (soil or loose gravel). Avoidance of such designs has come mostly from ungulates and may not apply to carnivores. Likewise, avoidance or fear of vertical walls may fade after animals adapt over time. Elaborate pathways are likely unnecessary and add cost.

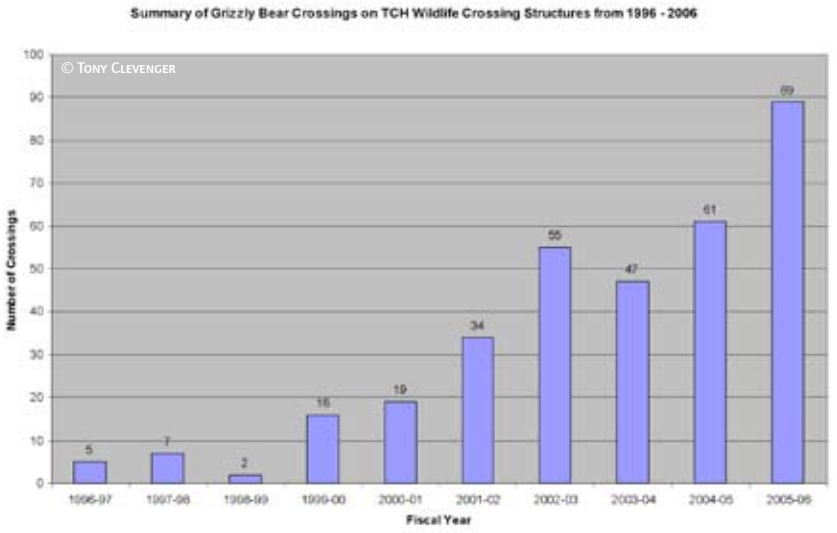
Fencing:

Fencing is as critical as the wildlife crossing structures and approaches. Most wildlife are extremely wary and will avoid confinement or unnatural situations. Given the choice between going through unfamiliar wildlife crossing structures and crossing highway pavement, many will choose the latter. Fencing forces wildlife to use the crossings. Over time, research indicates wildlife species will be more comfortable using wildlife crossings. Adaptations to using wildlife crossings may take up to five years. Young animals brought through wildlife crossings by their parents may readily accept crossings. Without fencing, most of these animals would not use the structures (Clevenger et al 2001).

Fencing is as critical as the wildlife crossing structures and approaches.

Fencing Length: There may be many fencing options. Properly placed and well-designed wildlife crossings require less fencing than crossings that are minimally accepted by wildlife. If animals have a high resistance to using the structure, they may travel along fences for long distances, trying to find less intimidating places to cross the highway. Continuous fencing linking multiple crossing structures, such as in Banff National Park and in some parts of Florida, is not feasible in most highway situations. In these cases, wing-fencing is employed. There are no simple answers to the length of wing-fences from a crossing structure. Sometimes there are natural features that funnel animals into wildlife crossings and perhaps wing-fencing can be limited to a few hundred feet on each end. Most of the time, wing-fencing should be built for ½ mile or more if large carnivores, deer, and elk are target species.

Fencing Placement: Wildlife fencing should be designed to minimize the corral or shoot effect. This is done by constructing fencing to the top of wildlife crossings, rather than the bottom, making the approach to a wildlife crossing as wide as possible (see examples on pg. 14). When fencing between lanes of a divided highway, build the fencing parallel to the highway for a short distance so it does not look like a narrow, confining chute.



Grizzly bear crossings on the Trans Canada Highway, Banff National Park.

Example of good fencing that ties into the top of a crossing structure: multi-plate arch on US Highway 40, Berthoud Pass, Colorado (top). Examples of poor fencing: corral effect fencing on US 550, New Mexico (bottom left), Livestock fencing blocking an underpass on Hwy 50 in Colorado (bottom right).

Large Carnivores: For large carnivores and deer and elk, 8'h page wire fencing is standard (Reed 1995). Bears, wolves, coyotes, and other carnivores may try to dig under fences or climb over. Burying fencing underground reduces the possibility of wildlife digging under the fence and also increases the lifetime of fencing reducing maintenance costs. Regardless of the degree of maintenance required, maintenance of fencing should be included in long-term project budgets.

Mid-Sized and Small Carnivores: Fencing is also important for small and mid-sized carnivores, although there is less information on what fence type works best. For many species, standard height highway fencing (4'h wire mesh) should be adequate. Skunks and other small carnivores will fit through 4" mesh size. In Europe, a variety of fencing material is used, including variable mesh fencing that has small-sized mesh openings at the bottom and 4"h x 4"w page wire on top. One half inch mesh screening is used in Europe for badger, amphibians and other small animals. Three or four foot high, 2"h x 4"w page wire should be adequate to funnel small carnivores into 36" culverts.

Often, 5-wire barb wire fencing is used to exclude livestock from using the crossing structures. Unfortunately, such fencing also may prevent or discourage wildlife from using the crossing. Recommended wildlife-friendly livestock fencing consists of a 3-wire design with minimal use of barbed wire, and the fencing should not be located immediately in front of structure entrances. The bottom wire should be high enough (normally 16 to 18 inches) to allow young animals to travel under the fence.

Escape Ramps:

Even under the best situations, wildlife find ways to enter the right-of-way. Escape ramps help larger species to avoid being trapped.

Elk using an escape ramp on US 550, Colorado.

Lane Configuration:

Often highway configuration can be used to benefit wildlife crossings. Constructing two wildlife crossings in a divided highway often results in a more effective situation than a single crossing spanning four to six traffic lanes. These options should be considered when highway widening projects are undertaken.

Highway Bridge Heights:

Wildlife commonly follow riparian habitat or drainages, and bridges may already exist in places where wildlife naturally cross highways. Highway bridges represent opportunities to

improve wildlife habitat connectivity, reduce wildlife mortality and reduce animal-vehicle collisions. Bridges are constantly being replaced as they become old and unsafe or highways are improved. For example, Oregon Department of Transportation qualitatively evaluated wildlife passage at a selection of bridges that were being replaced. Bridge design criteria that facilitate wildlife passage are the same as other wildlife crossings. For deer and most large carnivores, at least 10'h clearances are recommended. If elk, grizzly bear, or moose are present, bridge heights should be at least 12' to 13' high or more. For mid-sized and small carnivores, at least 3' or 4'h clearance above the highwater zone is recommended. There must be an adequate stream bank to allow use by target species.

Bridges are often high and open enough to allow enough sunlight to penetrate and allow growth of shrubs and grasses. Some bridges have been built with steel girders that make loud noises when traffic crosses. In Arizona, noise has been identified as extremely disturbing to elk trying to use crossings. Bridge material should minimize traffic noise.

Structure Size and Type: Design criteria that include structure size and type are "essential elements" for effective wildlife crossing structures. Size and type of structures affect both wildlife use and cost.

For example, a 13'h x 23'w multi-plate arch may cost $250,000. Open-span wildlife crossings often cost $1 million, or more. And, a wildlife overpass can easily cost $5 million or more. So, size and type of structure will matter to a highway engineer and highway departments. Small increases in structure size, or what may seem like subtle changes in design, may have a large effect on costs. All other things being equal, biologists should recommend the most cost-efficient design that will work for the target species.

Please refer to the table on page 18 for a matrix of structure size and type alternatives.

SPECIES-SPECIFIC CONSIDERATIONS

Large Carnivores: Large carnivores differ in their acceptance of wildlife crossings. For example, there is little information about the acceptance of jaguar to various crossing structure types, but 10'h x 20'w structures should be considered minimal. This estimate is based on what mountain lion would likely use, as recommendations for some species are based on known behaviors of similar-sized animals.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Grizzly bear and wolves are the most sensitive carnivore species with respect to wildlife crossing design. If grizzly bear or Rocky Mountain wolves are present, open-span underpasses or wildlife overpasses may be appropriate. The open-span underpasses in Banff National Park are approximately 13'h x 50'w in size and are used by grizzly bear and other large species. Wolves in Banff National Park have a preference for open-span underpasses. Grizzlies in Banff prefer overpasses that are 150' wide. Black bears used a variety of crossing structures including 150'w overpasses, open-span underpasses, 13'h x 23'w multi-plate arches and even 8'h x 10'w box culverts. Mountain lion, like black bear, used a wide variety of structures in Banff National Park (Forman 2003). In Banff National Park, the consensus of engineers and biologists is that the best overall design, based on a number of ungulate and carnivore species, is the open-span underpass.

Deer and elk are always target species for wildlife crossings where large carnivores are of concern. For most of the large carnivores and deer, 10'h structures should be considered minimal. If elk or grizzly bear are present, 12'-13'h should be considered minimal. Widths of at least 20' are recommended minimums for all large species. The least expensive steel multi-plate 13'h x 23'w crossing will likely be acceptable for black bear, mountain lion, and most other common carnivores. Reed et al 2000 recommends underpasses have an openness ratio or index of at least 2.0 to be effective.

Openness ratio or index of a wildlife crossing is determined by height x width divided by length. *Calculation must be in meters.*

Mid-Sized Carnivores:

Wildlife crossings for rare, mid-sized carnivores should be designed for larger animals to ensure their use by target species. These include ocelot, wolverine, and lynx. Using 10'h x 20'w structures, or larger, would be prudent until better research is developed (Gordon 2003). These would also be suitable for deer, black bear, and mountain lion. If elk are present, structures at least 13'h x 23'w are recommended.

Pine marten (top) and red fox (bottom) using a round culvert on US 287/26 east of Teton NP in Wyoming on the Togwotee Pass Highway.

For more common mid-sized carnivores, excluding coyote and bobcat, 36" pipes or box culverts should be considered minimum. If coyote and bobcat are primary target species, 13'h x 13'w box culverts or 48" culverts or pipes would likely be more effective. If deer are target species, structures suitable for them (10'h x 20'w minimum) will suffice for bobcats, coyotes and most other mid-sized and larger carnivores.

Little is known about river otter. However, there is anecdotal information that otter may avoid narrow culverts or bridges over streams, and elect to move out of the stream course and across roadways. Suitable highway crossings should include a natural stream channel at all flows and an unrestricted bank. Otter mortality has been reduced in the Netherlands where highway crossings are considered important conservation measures (Bekker 1998).

Small Carnivores:

Thirty-six inch pipes are commonly used for cross-ditching on large highways. A variety of small and mid-sized carnivores will use 36" pipes if adequate fencing is provided. Generally, species that dig holes, use burrows, or live or hunt in hollow logs or confined spaces will accept 36" pipes or box culverts. These include American badger, raccoon, skunks, American marten, fisher, mink, weasel, and foxes (Clevenger and Waldo 1999). A number of smaller mammals, reptiles, and amphibians also have been documented using culverts this size, or smaller. Cement pipes are preferable to corrugated steel, however, if steel pipes are used a layer of soil or gravel should be placed in the bottom.

WILDLIFE CROSSING CHECKLIST

- Does your state have a connectivity analysis? Is this analysis integrated into the Statewide Transportation Improvement Program (STIP)? ✓
- Are you working with a team that includes biologists, engineers, non-profits, and local planners? ✓
- Has the DOT integrated wildlife crossings in the initial phase of the highway project? ✓
- Have you identified target species? ✓
- Have you identified appropriate management of the land leading up to wildlife crossings? ✓
- Have you consulted with an expert on the most effective structure type and size for your target species (pg. 18)? ✓
- Is there a monitoring and maintenance plan in place? ✓

WILDLIFE MONITORING

In order to improve our scientific understanding of how various species respond to the size and type of wildlife crossings, it is important to conduct wildlife monitoring both before and after construction. Monitoring should be accomplished using scientific methodology and results, and recommendations should be published so others benefit from what is learned.

On individual highway projects monitoring can help fine-tune mitigation measures like fencing, wildlife approaches to structures, and human use levels. Monitoring also helps determine the amount and type of wildlife use structures receive. Monitoring is important to maintain agency and public support and should be included in major highway projects that include wildlife crossings. However, there must also be a reasonable balance between the level of monitoring and the funds available for projects. DOTs will be concerned about the costs of building wildlife crossings, maintenance, and the cost of monitoring. The cost-effectiveness and support for future wildlife crossings depends on good science. Wildlife crossings can be extremely expensive, sometimes costing many millions of dollars for single highway projects.

Minimal monitoring may be necessary for species or issues that have been researched repeatedly. For example, there have been a number of studies done on wildlife crossings for black bear and deer. Many other wildlife species, like lynx and jaguar, have little or no research.

Monitoring can range from low-cost wildlife track counts and roadkill surveys to medium-cost motion-triggered camera traps and genetic analyses of scat and hair samples. In order to fully understand fine scale movement, higher cost GPS telemetry of wildlife may be needed.

Coyote "caught" by a motion-triggered camera near I70, Vail Pass, Colorado.

GOING FORWARD TOGETHER!

Developing wildlife habitat linkages and building effective wildlife crossings is critical for the conservation of carnivores and other wildlife and can also be a win-win situation for the public, highway agencies, wildlife management agencies, and land management agencies. Success is greatest where communities and agencies have come together to share ideas and information for developing effective highway mitigation programs.

Engineers, biologists, and conservationists must work hand-in-hand to design and build wildlife crossings. While no two situations are exactly the same, as we learn from each success and challenge, subsequent wildlife crossings will be more effective.

Crossing Structure Type and Size - *Alternatives By Species**

Crossing Structure	Round Culvert	Concrete Box Culvert	Multi-plate Steel Arch	Open-Span Bridge, Bridge Extension	Overpass	Fencing
Large Carnivores						
Black Bear	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	8' page wire
Grizzly Bear		12'h+ x 32'w+	12'h+ x 23'w+	12'h+ x 50'w+	150'w	8' page wire
Mountain Lion	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	8' page wire
Wolf		12'h+ x 32'w+	12'h+ x 23'w+	12'h+ x 50'w+	150'w	8' page wire
Jaguar (research needed)	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	8' page wire
Mid-Sized Carnivores						
Bobcat	48"+	48"h+ x 48"w+	*structures for larger animals will be adequate for smaller animals.			4' wire mesh
Coyote	48"+	48"h+ x 48"w+	*structures for larger animals will be adequate for smaller animals.			4' wire mesh
Lynx (research needed)	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	4' wire mesh
Ocelot (research needed)	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	4' wire mesh
Wolverine (research needed)	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	4' wire mesh
Small Carnivores	36"+	36"+	*structures for larger animals will be adequate for smaller animals.			4"x 2" page wire, small mesh
Ungulates						
Deer	10'+	10'h+ x 20'w+	10'h+ x 20'w+	10'h+ x 20'w+	75'w+	8' page wire
Elk	12'+	12'h+ x 32'w+	12'h+ x 23'w+	12'h+ x 20'w+	75'w+	8' page wire

Passage Suitability for Species

=not adequate

=adequate

=best

**Information in this table was established from current studies, including recommendations from biologists and engineers with extensive wildlife crossing experience. The table is a general guide to designing and choosing appropriate structures for many target species. Other factors, such as terrain, engineering feasibility, cost, and site-specific conditions are always a consideration. The table is meant only as a broad guideline to assist in the selection of wildlife crossings.*

APPENDIX:

Small-sized carnivores include weasel *(Mustela nivalis)*, mink *(Mustela vison)*, skunks *(Mephitis spp.)*, red fox *(Vulpes vulpes)*, gray fox *(Urocyon cinereoargenteus)*, kit fox *(Vulpes macrotis*), swift fox *(Vulpes velox)*, opossum *(Didelphis viginiana)*, and American marten *(Martes americana)*.

Mid-sized carnivores include river otter *(Lontra canadensis)*, raccoon *(Procyon lotor)*, bobcat *(Lynx rufus)*, lynx *(Lynx canadensis*), wolverine *(Gulo gulo)*, ocelot *(Leopardus pardalis)*, coyote *(Canis latrans)*, jaguarundi *(Herpailurus yagouaroundi*), badger *(Taxidea taxus)* and fisher *(Martes pennanti)*.

Large carnivores include black bear *(Ursus americana*), grizzly bear *(Ursus arctos*), wolf *(Canis lupus*), mountain lion *(Puma concolor*) and jaguar *(Panthera onca*).

LITERATURE CITED:

Bekker, Hans (G.J.). 1998. Habitat fragmentation and infrastructure in the Netherlands and Europe. In: Evink, G.L.; Garrett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings the International Conference on Ecology and Transportation. Pgs 151-165.

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

Clevenger, A.P., and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14:47-51.

Clevenger, A. P., and N. Waldo. 1999. Dry drainage culvert use and design considerations for small and medium-sized mammal movement across a major transportation corridor. In: Proceedings of the Third International Conference on Ecology and Transportation, edited by G.L. Evink, P, Garret and D. Zeigler. FL-ER-73-99. Forida Department of Transportation, Tallahassee, FL. Pages 263-277.

Federal Highway Administration. 2006. Eco-Logical: an ecosystem approach to developing infrastructure projects. Report number: DOT-VNTSC-FHWA-06-01. 83 pages.

Forman, R. T. T., and D. Sperling, J. A. Bissonette et al. 2003. Road Ecology: Science and Solutions. Washington D.C., Island Press. 481 pages.

Foster, M.L., and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bullitin 23:95-100.

Gordon, Kelly M. 2003. Mule deer use of underpasses in western and southwestern wyoming. In: 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garret, and K.P. McDermott. Raleigh, N.C. Center for Transportation and the Environment, North Carolina State University. Pgs 309-318.

Hughes, W.E., A.R. Saremi, and J.F. Paniati. 1996. Vehicle-animal crashes: an increasing safety problem. Institute of Transportation Engineers Journal. 66:24-28.

Huijser, M. 2006. High-tech equipment may help reduce wildlife-vehicle collisions. MSU News Service.

Noss, R.F., H.B. Quigley, M.G. Hornocker, T. Merrill, and P.C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology 10(4):949-963.

Noss, R.F., and L.D. Harris. 1986. Nodes, networks, and MUMs: preserving diversity at all scales. Environmental Management 10:299-309.

Noss, R.F. 1987. Protecting natural areas in fragmented landscapes. Natural Areas Journal 7:2-13.

Noss, R.F. 1983. A regional landscape approach to maintain diversity. BioScience 33:700-706.

Reed, D.F. 1995. Efficacy of methods advocated to reduce cervid-vehicle accidents: research and rationale in North America. Conference presentee lors du colloque international "Route et faune sauvage", Strasbourg, Conseil de l'Europe, 5-7 juin 1985 and Sapporo, Japan, 27 Jan 1995.

Romin, L.A. and J.A. Bissonette. 1996. Deer-vehicle collisions: Status for state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24 (2):276-283.

Ruediger, Bill and John Lloyd. 2003. A rapid assessment process for determining potential wildlife, fish and plant linkages for highways. In: 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garret, and K.P. McDermott. Raleigh, N.C. Center for Transportation and the Environment, North Carolina State University. Pgs 309-318.

Ruediger, Bill. 1998. Rare carnivores and highways – moving into the 21st Century. In: Evink, G.L.; Gar rett, P.; Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings the International Conference on Ecology and Transportation. Pgs10-16.

Ruediger, Bill. 1996. The relationship between rare carnivores and highways. In: Evink, G.L.; Garrett, P.;Ziegler, D.; and J. Berry (Eds.) Trends In Addressing Transportation Related Wildlife Mortality. Proceedings of the Transportation Related Wildlife Mortality Seminar.

Ward, A.I. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Transportation Research record 859:8-13.

Watson, Mark and Jon Klingel. 2000. Literature summary assessing methods for reducing deer-vehicle accidents. New Mexico Department of Fish and Game Website. www.wildlife.state.nm.us/conservation/habitat_handbook/Deer-VehicleAccidents.htm

FURTHER INFORMATION:

Center for Transporation and the Environment: http://cte.ncsu.edu/cte/
Rockies Wildlife Crossing Field Course: www.restoretherockies.org/field_course.html
WFT Listserve: www.itre.ncsu.edu/cte/gateway/WFTlistserv.asp
ICOET: www.icoet.net
Western Transportation Institute: www.coe.montana.edu/wti/
Defenders of Wildlife: www.defenders.org/habitat/highways/
Wildlife Crossings Toolkit: www.wildlifecrossings.info/contact.htm
Arizona Wildlife Crossing Guidelines: www.azgfd.gov/hgis/guidelines.aspx

STATEWIDE CONNECTIVITY PLANS
Arizona: 2006. Missing Linkages.
Colorado: SREP, 2005. Linking Colorado's Landscapes. www.restoretherockies.org/linkages.htm
New Mexico: 2003. Critical Mass Workshop.
Utah: West, Paul. 2006. Wildlife Connectivity Across Utah's Highways.

STATE WILDLIFE ACTION PLANS: www.teaming.com/state_pages.htm

Additional resources as well as links to the above mentioned statewide plans can be found at www.CarnivoreSafePassage.org

1 meter = 3.2808399 feet
1 foot = 0.3048 meter

Final version, February 20, 2007

www.CarnivoreSafePassage.org