Innovative Approaches to Wildlife/Highway Interactions

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A Self Study Guide

Produced to Accompany the U.S. Fish and Wildlife Service
Training DVD: "Innovative Approaches to Wildlife/Highway Interactions"

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Appendices:

Introduction/Overview

This study guide is designed to accompany the NCTC training video/DVD:

Innovative Approaches to Wildlife/Highway Interactions

The purpose of the training is to provide instruction to U.S. Fish and Wildlife Service and other natural resource managers and engineers on state-of-the-art approaches for addressing wildlife-highway interactions. Highways, as well as low volume roads, are often a major source of impact affecting wildlife on public and private lands. Natural resource professionals must interact with highway engineers and other staff concerning impacts of roads and highways in areas of joint concern. Determining the most effective approach to any wildlife/highway issue requires knowledge of successful innovative approaches and solutions used to address road impacts. This Study Guide, along with the training video, will provide an instructional overview of ongoing approaches, technologies, and structures being used across the country to provide cooperative solutions to observed impacts or other wildlife concerns shared by both biologists and highway professionals.

The Study Guide categorizes wildlife crossing structures from the smallest structures to the largest ones. Generally, small structures are designed for smaller animals and larger structures can accommodate small and large animals. A table listing the various taxa served by each type of structure can be found in the appendix. Definitions of terms are bolded in the Study Guide at the location introduced by the video. Key points in bold elaborate on important concepts suggested by the video.

Most of the wildlife crossing structures shown in this video are distinguished by their solid history of long term effectiveness monitoring. Although to date nearly 800 wildlife crossing structures are now in place in North America, most do not have long term, rigorous monitoring to determine effectiveness or to identify adaptive management improvements. The lessons learned from the landmark studies shown in this video have been adapted to new structures, but we still have much to learn on wildlife and highway interactions. We encourage biologists to request assistance for complex highway projects involving large scale structures. We further encourage well-designed studies on future structures.

Note: The ***Innovative Approaches to Wildlife/Highway Interactions*** *training video/DVD and this Study Guide are designed to meet the requirements for the National Conservation Training Center course:* ***Innovative Approaches to Wildlife/Highway Interactions (CSP7089)****. If you would like to receive credit from NCTC for completing CSP7089, including a certificate and completion recorded on an NCTC transcript, please be sure to use the questions in this guide and follow the instructions at the end to apply for the course. Also note that any reference, mention, or discussion of specific products, companies, web sites, studies, or management techniques in this Study Guide or the training video/DVD, does not imply endorsement by the U.S. Fish and Wildlife Service, or the National Conservation Training Center.*

Objectives

After completing the *Innovative Approaches to Wildlife/Highway Interactions* video lesson along with the "question and answer" sections in this study guide, you will be able to:

- ✓ Define how highways interact with wildlife, including impacts;
- ✓ List types of structures that reduce wildlife impacts from highways; and
- ✓ Describe the role of interdisciplinary networking and partnerships important to the highway project planning process related to wildlife structures.

Video Introduction

Definition: Road ecology or transportation ecology

- ➢ Is the applied study of ecology as it refers to the interactions of the built infrastructure on ecosystems.
- ➢ In broadest terms, transportation ecology includes the interactions of biotic and abiotic elements with highways.
- ➢ In this video, the scope of the discussion is narrowed to primarily deal with terrestrial animals and highways, with mitigation focused around the two impacts of reducing vehicle-caused wildlife mortality and increasing permeability for wildlife movement across highways.

Video Part 1: Small Underpasses

A. Boonsboro, Maryland – Box Turtles

- **Definitions:**
  - ➢ **Small culverts**
    - – have a span, or width across, of 5 feet or less.
    - – can be box culverts or metal pipes.
  - ➢ **Retrofitting**
    - – is a modification of an existing structure to enable it to be used for passage by wildlife or aquatic species.
    - – usually occurs for culverts or bridges which are already in place for water conveyance purposes.
    - – in the Boonsboro example, adding silt fencing to the existing structures enabled the existing culverts to be used by turtles because the fencing diverted turtles to them.

- **Key Point**
  - ➢ Fences are used to barrier animals from accessing the road, thus reducing mortality from vehicles, and to divert animals to safer crossing locations such as wildlife crossing structures.

- **Review Questions**
1. Why was the silt fence used in the Boonsboro example?

2. What percentage of turtles was found to be using the existing culverts after the silt fencing was installed?

3. How was the original Boonsboro project funded?

4. How was the permanent project funded?

5. Why is the fence opaque?

6. Why would a wildlife manager choose to retrofit an existing structure instead of construct a new one?

7. What are a few ideas to retrofit existing structures?

B. Montana – Dry Shelf

- **Key Point**
  - ➢ Even animals that use riparian areas for travel corridors often prefer to travel on unsubmerged surfaces, so dry areas alongside water enhance structure effectiveness.

- **Review Questions**
1. Why does a dry shelf enhance wildlife use through a structure?

2. What caution may be needed if a manager determined a dry shelf may be a useful retrofit?

3. In the Montana dry shelf case history, a vole tube was shown. What is a ‘vole tube’, and how does this structure shed light on why small animals tend to prefer small underpasses?

C. Amherst, Massachusetts – Spotted Salamanders

- **Key Points**
  - Small animals are typically more comfortable in enclosed spaces because of the need for hiding cover from predators.
  - The tight space of some culverts is a useful behavioral accommodation for these species.
  - Large open structures can accommodate small animals if additional cover, such as boulders, is provided for hiding.
  - Fencing is key to the functionality of wildlife crossing structures. Fencing needs to be designed to work with the behavioral and anatomical features of the target species or group that the crossing structure is designed to serve.
  - Barriers with lipped, or concave, tops can be designed to serve small or large species. The concept works for any species that tends to climb fences.
  - Create structures for multiple species if possible.

- **Review Questions**

1. In the Amherst spotted salamander case, a modified type of small underpass was used. What was it called and why was it used?

2. What were some of the key issues considered when designing crossing structures for spotted salamanders at Amherst?

3. What design feature keeps spotted salamanders from climbing over the fence and onto the road in the Amherst example?

4. The Amherst project has been monitored for several years. What results have been obtained from the monitoring?

<u>Video Part 2</u>: Medium Underpasses

A. Paynes Prairie, Florida – Reptiles and Amphibians

- **Definition: Medium Underpasses**
  - Are larger than 5 feet across and typically less than 8 feet across.
  - Allow for greater openness than small underpasses but are too small for deer.
  - Three categories are typically found:
    - box culverts: consist of four sides made of concrete or wood
    - continuous culverts: rounded and are made of corrugated metal pipe (CMP), metal, concrete, or wood
    - open bottom culverts: square or rounded and are made of CMP, metal, concrete, or wood

> ***Ecopassage***
> *Ecopassage is a term occasionally used in Europe for wildlife crossing structures such as underpasses, but is not commonly used in North America. In the Payne's Prairie example, it refers to the system of several underpasses and the barrier.*

- **Key Points**
  - Fencing is the primary method of reducing vehicle-caused wildlife mortality, and reducing animal-vehicle collisions that affect human safety, because it keeps wildlife off the highway.
  - Wildlife crossing structures (underpasses or overpasses) are the primary method of maintaining safe wildlife movement across the highway. Together, these two features are the most effective system to meet both objectives.
  - Maintenance is key to effective functioning of fencing and wildlife crossing structures.
  - Ensure that a discussion on agency responsibility, timing and funding of maintenance occurs prior to project completion.
  - When setting objectives for the effectiveness of wildlife crossing structures and fencing, it is important to determine what species are being impacted and to what level.
  - Three population-level impacts to consider hierarchically are: 1) genetic interchange, 2) demographic dispersal, and 3) daily or seasonal movements for life history requisites. Additionally, human safety might be an objective if collisions with larger animals are a factor.

- **Review Questions**

1. In the Paynes Prairie case history, an unusual partnership developed among stakeholders. Why was the coalition important to other projects across the country?

2. What were the two major objectives of the system of wildlife crossing structures and barriers at Paynes Prairie?

3. What were some species found to be using the medium underpasses at Paynes Prairie?

4. Describe the barrier wall and its functions.

5. What maintenance issues did the transportation department face with the Paynes Prairie project?

6. Has monitoring shown the crossing structures and barriers to be effective in mitigating vehicle-caused mortality and habitat fragmentation?

Video Part 3: Large Underpasses

> ***Wildlife Collision Statistics***
> *An estimated one to two million large animals (mostly deer) are killed by vehicles each year in the US. Approximately 200 people are killed in these collisions with deer, and another 29,000 people are injured. Mitigation measures save lives, property damage and also the ecological values of the animals.*

- **Definition: Large Underpass**
  - Is defined as bridges or culverts large enough to accommodate mule and/or white-tailed deer or larger animals.
  - For most areas of the country, this size structure is a minimum of 20 feet span and 8 feet rise.
  - In some situations, especially if a structure passes under a narrow road so the interior length is not great, 8 ft by 8 ft underpasses are suitable for deer.

A. Utah – Deer

- **Key Points**
  - Large underpasses designed for mule or white-tailed deer need several design features to be optimally effective.
    - visibility especially in the horizontal plane, room to maneuver, and moderated noise are key features.
    - size, defined above, can vary in height and width but needs to increase in size as the length increases in order to increase visibility.
    - shape may be important but current studies have shown deer have accepted many shapes provided the size is adequate and horizontal visibility is maintained.
  - A factor in designing effective underpasses for large animals, including deer, is the interval between structures.
  - The vagility (the capacity or tendency of a species to move about or disperse in a given environment) of the target species will help inform the minimum number of structures needed in a given area for the necessary level of movement. With lower vagility animals or those with small home ranges, more structures may be of greater benefit than fewer larger structures. In other cases, the choice may be several minimally acceptable structures compared with one large, highly effective structure.

- **Review Questions**
  1. In the Utah example, what design feature appeared to result in a greater repel rate?

B. Highway 260, Arizona - Elk

- **Definitions**:
  - **Traffic Volume**
    - is the number of vehicles passing through a point in a given time period, normally sampled and reported as an Average Daily Traffic (ADT) or Average Annual Daily Traffic (AADT).
    - as traffic volume increases, the gaps between vehicles decrease, thus making it more difficult for animals to 'run the gaps' and safely cross the highway.
  - **Escape Structures**
    - are structures designed to allow animals trapped on the highway side of an exclusion fence a means to safely return to the outside of the fence.
    - several escape structure types are available, and design innovations continue to be tested.
    - escape structures tend to be species- or guild-specific, and can be large or small.
  - **End-runs**
    - occur when animals follow a fence to its end and then cross the highway at that location.
    - end-runs can be reduced with adequate opportunities to cross the highway safely (with crossing structures).

- **Key Points**
  - Multiple studies have shown that animals may take long periods to habituate to crossing structures. Even less than perfectly designed structures can be improved by effective fencing.
  - Traffic volume is a good predictor of impacts to animals because as traffic volume increases, animals have fewer options to avoid being hit.
  - As traffic volume increases, vehicle-caused mortality may decrease for some species because they begin to avoid attempting to cross the highway, thus increasing the barrier effect.

- **Review Questions**
  1. In the Arizona SR 260 case history, elk were being hit by vehicles increasingly as what occurred?

2. From an interagency planning effort, the SR 260 highway improvement was exemplary in several ways. What features helped make this project successful?

3. The Sharp Creek Bridge is an example of a large underpass. At this site, what design features encouraged wildlife use?

4. The two large underpasses at Little Grass Valley are similar in many respects. Monitoring showed considerably different levels of use by elk. Why?

5. How high were the effective elk fences on the SR 260 project?

6. The SR 260 project tested several types of fencing. What other types were mentioned?

7. What are some pros and cons of boulder fences?

8. How high should an escape ramp (or 'jumpout') be?

9. Several types of materials can be used to construct jumpouts. What else was used on the SR 260 project?

10. One-way gates are often used as escape structures. How effective are they compared with escape ramps?

11. Given that fencing must end somewhere, what are methods to place fence ends to minimize end-runs?

C. State Route 68, Arizona – Bighorn Sheep

> ***Become Involved Early in the Process***
> *Early involvement and partnerships enable win-wins to be collaboratively worked out early in the design process. Late involvement in projects by concerned agencies or stakeholders make it difficult for transportation planners to make changes. Once highway designs are 90% complete, it is very difficult and expensive to make substantial changes.*

- **Review Questions**
  1. In the Highway construction projects are major earth-disturbing activities. What are some examples of impacts outside of the highway footprint?

D. Alligator Alley, Florida – Florida Panthers

A. Key Points

- Two major impacts of highways on wildlife species are:
  - mortality from vehicle-caused collisions
  - habitat fragmentation from the barrier effect of highways
- Locating crossing structures in suitable locations is a multi-scalar process.
- Large scale habitat connectivity assessments are available in some states.
- Specific crossing structure location depends partially on topography and available landownership, as well as specific data gathered such as known animal movements in the area.

- **Review Questions**

1. In the example of Florida's Alligator Alley, a major emphasis was to reduce vehicle-caused mortality from further endangering the federally-listed Florida panther. Installing wildlife crossing structures for panthers had what corollary benefits?

2. Besides the Florida panther, what other species have been documented using the underpasses along Alligator Alley?

3. An important design consideration for wildlife crossing structures is locating them where the target species are likely to find and use them. How was this determined for the Florida panther?

4. Bridge extensions are bridges built larger than the minimum needed to accommodate normal high water. What are some benefits to bridge expansions?

5. Obsolete bridges in the tens of thousands are being replaced across the country. What opportunities do these replacements represent for natural resource managers?

Video Part 4: At-Grade Crossings

- **Definition: At-Grade Crossings**
  - Are accommodations conceptually similar to pedestrian crosswalks at the same level as traffic flow, rather than structures such as bridges or culverts.
  - Technologies in this area of transportation ecology are rapidly being developed and new innovations are expected in the future.
  - Currently, most at-grade crossing mitigation measures are designed only for large animals as part of a safety program.

- **Review Questions:**

1. At-grade crossing solutions might be a good choice in what situations?

2. What are the two general categories of at-grade crossings currently?

3. Access roads (side roads) onto the highway are problematic for keeping animals off the highway because it is difficult to allow vehicles to cross through fencing without also enabling animals to pass through. What are two possible solutions mentioned in the video?

4. Several other at-grade crossing solutions have been tested. Two types of approaches are used: change driver behavior or change wildlife behavior. Which of these approaches has proved to be most effective?

Video Part 5: Overpasses

A. Banff National Park, Canada

- **Definition: Wildlife Overpasses or Overcrossings**
  - Are structures that enable animals to cross over the traffic.
  - Although not all overpasses designed for wildlife incorporate soil and vegetation on the upper surface, almost all of the newest designs attempt to recreate local ecosystem conditions with native plants and soil.
  - The minimum width of wildlife overpasses varies by the target species, and is an active area of research

- **Review Questions**
  1. Why are overpasses considered suitable for animals that may not use enclosed structures such as bridges or culverts?

  2. Banff National Park in Canada is the location of the longest-running monitoring study of wildlife crossing structures in the world. For the large carnivores of the northern Rocky Mountains, what size width of wildlife overpass is currently deemed appropriate?

  3. How effective have Banff's wildlife crossing structures been to reduce ungulate/vehicle collisions, and all animal/vehicle collisions?

  4. Reduction of vehicle-caused mortality is one measure of effectiveness of wildlife crossing structures. Another is the population-level dispersal benefits of structures, a much more difficult metric to measure. How is this being investigated in Banff National Park?

<u>Video Conclusion</u>: Putting it Together (U.S. 93)

- **Key Points**
  - ➢ The Montana US 93 case history is an example of an approach that the Federal Highway Administration calls Context Sensitive Solutions. Context sensitive solutions (CSS) is a collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources, while improving or maintaining safety, mobility, and infrastructure conditions (FHWA 2007).
  - ➢ Numerous studies have indicated that a suite of mitigation measures that includes diversion/barrier fencing, wildlife crossing structures, and escape structures are the most effective mitigation for vehicle-caused wildlife mortality and loss of wildlife movement across highways.
  - ➢ Expanding bridges and culverts to accommodate wildlife over the minimal size needed to convey water flow has benefits not only for wildlife, but also for hydrologic issues associated with climate change-induced flood events.
  - ➢ Long term monitoring is planned for both the US 93 project and Banff National Park. Long term monitoring studies have shown that wildlife use of crossing structures increases slowly over time, over as many as 10 years varying by species. Short term monitoring studies less than this duration may mislead investigators on the true effectiveness of crossing structures.

- **Review Questions**
  1. Why is it important to strategically design and place wildlife crossing structures with an integrated purpose?

  2. The Montana US 93 case history provides a number of lessons on large scale integrated, interagency planning. These long term efforts over a number of years resulted in a change of paradigm on how to plan highways in areas with wildlife impacts. According to the video, what was a major change in the way of thinking on how to design a highway?

  3. A feature of the long stretch of US 93 within the project area is its mix of wildlife crossing structures. Based on concepts shown earlier in this video, why would a mix of crossing structures provide ecological benefits?

4. Although the video does not identify all of the mitigation measures in the complex US 93 project, several key features are identified. What are these?

5. On the US 93 overpass, soil and vegetation will provide what benefits to wildlife? (Hint: consider concepts introduced earlier in the video as well.)

6. A ‘green screen’ is designed for the US 93 wildlife overpass. What is its purpose?

7. The US 93 project placed many of its wildlife passages in riparian areas. Why is it cost-effective to place wildlife crossing structures at drainages?

8. The US 93 project included substantial monitoring, before and after construction. What are two post-construction monitoring methods used to determine the effectiveness of the wildlife crossing structures?

9. US 93 offered many lessons learned for adaptive management. Overall, what is one key partnership lesson to be gained from their experience?

10. The use of wildlife crossing structures is relatively new in North America, and the public is awakening to their use. What might be some public relations benefits of monitoring wildlife crossing structures?

11. Can we have our cake (a fast, efficient human transportation system) and eat it too (allow wildlife to move across the landscape)?

Appendices

Appendix 1: Table - Terrestrial Wildlife Crossing Structure Types (By Function)

This table is a generalized overview of the types of structures used for wildlife passages. Terrestrial wildlife species vary in their preference for structure types, and some species are generalists while others narrowly prefer certain attributes.

Crossing Structure Class	Function	Approximate Dimension Range (Span x Rise)	Structure Examples	Species Examples	Wildlife Behavioral Attributes
Class 1: Small Underpass	Provides enclosed protection for small animals that require cover.	Metal pipe culverts or small box culverts 1.5 m (5') span or less	Small bridges, dry culverts, and ephemerally flooded drainage culverts. Continually flooded drainage structures have limited functionality for terrestrial species but may function for some aquatics.	Amphibians, reptiles, small mammals and some medium-sized mammals (badger, fox, bobcat). Aquatic species include fish, aquatic amphibians, and invertebrates.	Small animals that prefer cover or do not mind confinement.
Class 2: Medium Underpass	Provides some cover yet more openness than Class 1 structures for animals smaller than deer. If water is conveyed, allows for stream simulation including unwetted natural banks.	Underpasses larger than 1.5 m (5') span, to 2.4 m (8') span x 2.4 m (8') rise	Box culverts, arch pipes and other culvert shapes, small bridges.	Coyote, bobcat, ocelot, lynx and some large carnivores (black bear, puma); alligator.	Medium sized mammals that require some cover and some openness to see through passage.
Class 3: Large Underpass	Provides an approximate minimum for ungulates, especially deer, and other species that require visibility, maneuverability, and moderated noise. May allow some natural processes including vegetation growth and stream processes.	Underpasses with minimum dimensions: 6.1 m (20') span x 2.4 m (8') rise, or 3.1 m (10') span x 3.1 m (10') rise, and open span bridges	Box culverts, large arch pipes, bridges including open span bridges. Multiple chambered structures are considered as individual units.	Ungulates use structures in approximate proportion to their size (ie, deer can use smaller structures than elk or moose) although pronghorn require larger structures (minimum 18.3 m span x 5.5 m rise). Large carnivores (wolf, grizzly bear, black bear, puma).	Larger mammals that require structures of a minimum size for passage.
Class 4: Extensive Bridge (includes Viaducts)	Allows ecosystem processes to permeate highway such as wetland water flow, vegetation growth, and entire floodplains. Provides excellent horizontal visibility for animals requiring openness.	Bridge extending over several spans. Designed for each site so dimensions vary. May allow more sunlight under structure than other types.	Viaducts are long bridges elevated over the landscape in a series of smaller spans, often connecting points of equal height. Typically over wetlands, steep terrain.	Most species including wetland species, birds, pronghorn.	Viaducts are particularly good for wary species including carnivores that may not approach other structures, or low mobility species such as mollusks that require vegetation throughout the structure.
Class 5: Wildlife Overpass	Provides an open top and expansive visibility of the horizon for animals preferring unenclosed spaces. Allows full sunlight and precipitation for vegetation growth. May allow small, sunlit water features.	Overpass structure for wildlife to pass over roadway, as small as 6.7 m (22') wide, but preferably $\geq$50 m (164') wide. Large highway traffic tunnels can be very long and provide vast amounts of undisturbed habitat.	Overpasses with soil and plant growth. A tunnel for highway traffic under intact bedrock, soil and vegetation would function as a wildlife overpass regardless of the original objective of the structure.	All ungulates (pronghorn not proven yet), carnivores (bear, puma, forest carnivores). Songbirds and insects including butterflies.	Any species that requires natural habitat, sunlight or ambient conditions for movement.

Crossing Structure Class	Function	Approximate Dimension Range (Span x Rise)	Structure Examples	Species Examples	Wildlife Behavioral Attributes
Class 6: Specialized Culvert	Allows outside environmental conditions to occur within the entire structure, including light, temperature and moisture.	Current designs are small culverts less than .5 m (24") span but could be larger structures.	Trench drains and slotted culverts.	Reptiles and amphibians	Reptiles and amphibians that require ambient outside conditions to survive and disperse, or to orientate during movements.
Class 7: Aerial Bridge	Provides an aerial passage for animals that typically do not descend below tree canopy to ground.	Adequate to cross all traffic lanes. May be connected to trees in the median.	Treetop rope bridges, or modified wire or metal structures. Towers may function the same way for some species (such as flying squirrels).	Squirrels, arboreal rodents, opossum, monkeys. Potential for insects and plants.	Species that move through the canopy rather than on the ground surface.
Wildlife Fence	Functions to barrier access to the roadway and to divert the animals towards a suitable crossing location.	Dimensions vary by target species from small concrete or polymer curved structures a few centimeters in height, to 2 m page wire mesh for high-jumping mammals.	Types vary greatly but can be distinguished from standard right-of-way fencing which is primarily only effective for livestock. Concave or lipped concrete walls; buried small mesh wire; 2 m page wire.	All animals, including some birds, can be effectively barriered from the roadway with fencing designed to match their physical and behavioral characteristics.	Wildlife tend to have 4 types of fence avoidance behaviors: Pushing, digging, climbing, or jumping.

May 28, 2010 version-- Innovative Approaches to Wildlife and Highway Interactions. Table modified from NCHRP 25-27 "Evaluating the Use and Effectiveness of Wildlife Crossing Structures"

Appendix 2: Answers to Comprehension Questions

Video Part 1: Small Underpasses

A. Boonsboro, Maryland – Box Turtles

1. Why was the silt fence used in the Boonsboro example? Box turtles at the Boonsboro site were barriered from the road by the silt fence and diverted towards the existing culverts.

2. What percentage of turtles was found to be using the existing culverts after the silt fencing was installed? Monitoring indicated that about 20-25% of the turtles were using the culverts. Cameras at the culverts could individually identify turtles.

3. How was the original Boonsboro project funded? Volunteers built the temporary silt fence and monitored the effectiveness of the fence and culverts.

4. How was the permanent project funded? A federal grant program managed by each state department of transportation, called Transportation Enhancements (under the Surface Transportation Bill SAFETEA-LU) funded the permanent project (not shown on the video). The grant was obtained through the partnership of the stakeholders at Boonsboro and the Maryland DOT.

5. Why is the fence opaque? When box turtles (and some other turtles) cannot see through a fence, they tend to turn and follow the fence instead of trying to push through or under it. This enables the fence to funnel the turtles towards the culverts so they can cross safely under the road.

6. Why would a wildlife manager choose to retrofit an existing structure instead of construct a new one? It can make use of structures already existing on the landscape, and in difficult economic times it is a cost-effective approach. Typically these are drainage structures for water, and so are placed in natural wildlife travelways.

7. What are a few ideas to retrofit existing structures? Remove obstructions from entrances to culverts; create pathways through impassable boulder riprap; add dry shelf material through structures submerged in water.

B. Montana – Dry Shelf

1. Why does a dry shelf enhance wildlife use through a structure? It allows an unsubmerged surface for animals to walk on.

2. What caution may be needed if a manager determined a dry shelf may be a useful retrofit? Construct the shelf so that water flowing through is unobstructed. (Consult an engineer and/or hydrologist for assistance.)

3. In the Montana dry shelf case history, a vole tube was shown. What is a 'vole tube', and how does this structure shed light on why small animals tend to prefer small underpasses? A vole tube is a small diameter pipe that is used to provide the sensation of cover to small (prey) animals that do not like to be exposed (to predators). This same principle is why many small animals prefer the enclosed spaces of small underpasses over the open space of larger structures

C. Amherst, Massachusetts – Spotted Salamanders

1. In the Amherst spotted salamander case history, a modified type of small underpass was used. What was it called and why was it used? It is called a slotted culvert (or trench drain), and it is used to allow ambient light, humidity, and temperature to enter into the culvert to make it more accommodating to salamanders (or other permeable-skinned animals).

2. What were some of the key issues considered when designing crossing structures for spotted salamanders at Amherst? Key issues considered were the location of the structures along the road, how to create the entryways to encourage salamanders to enter the structures, how to deal with standing water and runoff, and how to design species-appropriate fencing.

3. What design feature keeps spotted salamanders from climbing over the fence and onto the road in the Amherst example? The fence uses a lipped top to topple salamanders back away from the road.

4. The Amherst project has been monitored for several years. What results have been obtained from the monitoring? The investigators found no evidence of road toxins in the structures. Structures that were modified to include more light were more effective, and

newer designs were adapted to have more light as well as airflow. Smaller structures may be possible provided adequate light, moisture and temperature met the needs of the salamanders. Create structures for multiple species if possible.

<u>Video Part 2: Medium Underpasses</u>

A. Paynes Prairie, Florida – Reptiles and Amphibians

1. In the Paynes Prairie case history, an unusual partnership developed among stakeholders. Why was the coalition important to other projects across the country? The target species were not federally-listed under the Endangered Species Act, so the coalition of stakeholders had no legal standing to protect the multitude of species in the marsh. This indicated to transportation planners that common species impacted by highways was a growing public concern. It was also a collaborative process of biologists, engineers, and concerned citizens.

2. What were the two major objectives of the system of wildlife crossing structures and barriers at Paynes Prairie? The 'ecopassage' was designed to keep animals off the highway to reduce mortality (with barriers) and to allow them to safely pass underneath the highway (to maintain movement throughout the Paynes Prairie marsh).

3. What were some species found to be using the medium underpasses at Paynes Prairie? Otters, alligators, frogs, coyotes, raccoons, opossums. Other species are recorded in published papers on monitoring results.

4. Describe the barrier wall and its functions. The barrier wall is a lipped wall similar in concept to the Amherst salamander fence but much larger to deal with larger climbing species, tipping them over at the top before they can climb out. It is made of precast concrete to reduce onsite environmental damage. Smooth concrete reduced the ability of climbing species to grasp the surface.

5. What maintenance issues did the transportation department face with the Paynes Prairie project? Vegetation control to make the lipped wall function correctly. Providing access to both sides of the wall.

6. Has monitoring shown the crossing structures and barriers to be effective in mitigating vehicle-caused mortality and habitat fragmentation? Yes, for most species. Some species, such as tree frogs, continue to climb the barriers and are killed by vehicles.

Video Part 3: Large Underpasses

A. Utah – Deer

1. In the Utah example, what design feature appeared to result in a greater repel rate? Underpasses that were very long (ie, went across several lanes of traffic) showed less use by deer than shorter structures.

B. Highway 260, Arizona – Elk

1. In the Arizona SR 260 case history, elk were being hit by vehicles increasingly as what occurred? Traffic volume increased the rate of elk/vehicle collisions.

2. From an interagency planning effort, the SR 260 highway improvement was exemplary in several ways. What features helped make this project successful? Interagency partners were willing to try and learn new approaches. Adaptive management occurred where lessons learned were implemented later in the project. New innovations were tried, such as new fencing types.

3. The Sharp Creek Bridge is an example of a large underpass. At this site, what design features encouraged wildlife use? The bridge was wide enough to allow unsubmerged edges of the creek as well as for adequate creek flow. Hiding cover was retained near the structure.

4. The two large underpasses at Little Grass Valley are similar in many respects. Monitoring showed considerably different levels of use by elk. Why? Monitoring videos indicated that elk were suspicious of high ledges on the large walls that were apparently perceived as predator hiding locations.

5. How high were the effective elk fences on the SR 260 project? 8 feet.

6. The SR 260 project tested several types of fencing. What other types were mentioned? A fence of piled boulders several feet wide (with no spaces in between boulders) was used in some places. An electric fence top wire was used as well as a fully electric fence. (These electric fences were not high-tensile electric fence.)

7. What are some pros and cons of boulder fences? Boulders are maintenance free, so that the higher cost of installation is eventually evened out compared to typical wire fence. Boulders work best with ungulates and not as well with other animals such as mountain lions that can walk over boulders. Heavy snow can bury them and cause them to be ineffective.

8. How high should an escape ramp (or 'jumpout') be? Escape ramps work on the principle that it is less intimidating to jump away from the highway than to jump into it, so the height needs to compromise the fear of jumping out (down) with the ability to jump up. Thus, for elk the height was adaptively determined to be about 6 feet, but the height is species-specific. Just above eye-level appears to be a good starting height.

9. Several types of materials can be used to construct jumpouts. What else was used on the SR 260 project? Concrete instead of wooden boards, which reduced long term maintenance costs. Earthen embankments can also be used.

10. One-way gates are often used as escape structures. How effective are they compared with escape ramps? Escape ramps (jumpouts) are about 8 times more effective than one-way gates.

11. Given that fencing must end somewhere, what are methods to place fence ends to minimize end-runs? Try to end the fence in a location beyond the species' suitable habitat, such as upland habitat for wetland species, or a change of vegetation type. This is often not possible, so ending a fence in a straight stretch of highway may allow drivers greater visibility to see and avoid animals.

C. State Route 68, Arizona – Big Horn Sheep

1. In the Highway construction projects are major earth-disturbing activities. What are some examples of impacts outside of the highway footprint? Staging areas for construction equipment can use a large amount of acreage, typically near the construction site but not necessarily on the highway footprint. Borrow material is often required in massive quantities, and must come from somewhere. Waste materials conversely may need to be dumped if they are in excess of the quantities needed.

D. Alligator Alley, Florida – Florida Panthers

1. In the example of Florida's Alligator Alley, a major emphasis was to reduce vehicle-caused mortality from further endangering the federally-listed Florida panther. Installing wildlife crossing structures for panthers had what corollary benefits? Crossing structures for species that were not necessarily safety risks to drivers introduced the concept of multiple-species mitigation for highway impacts.

2. Besides the Florida panther, what other species have been documented using the underpasses along Alligator Alley? Black bear, alligator, raccoons, turkey, white-tailed deer, many birds. "Most of the species" in the area.

3. An important design consideration for wildlife crossing structures is locating them where the target species are likely to find and use them. How was this determined for the Florida panther? Data was available that showed travel corridors for Florida panthers and other species. The crossing structures were located along travel corridors.

4. Bridge extensions are bridges built larger than the minimum needed to accommodate normal high water. What are some benefits to bridge expansions? Expanded bridges allow for dry unsubmerged pathways along watercourses for wildlife travelways. They allow unimpeded, natural stream flow for wildlife and aquatic species as well as hydrologic function. Accommodating larger areas allows for greater flood flow, especially for climate-change induced pulse events.

5. Obsolete bridges in the tens of thousands are being replaced across the country. What opportunities do these replacements represent for natural resource managers? Bridge extensions can be encouraged by natural resource managers because of their multiple resource benefits.

Video Part 4: At-Grade Crossings

1. At-grade crossing solutions might be a good choice in what situations? At-grade crossings are typically less expensive than installing an overpass or underpass for wildlife, although typically less effective and often single-species oriented. In urbanized areas or those with multiple access roads, fencing and crossing structures are difficult to construct. Topography may not allow for underpasses or overpasses.

2. What are the two general categories of at-grade crossings currently? Signing is the most common, which can be as simple as the familiar yellow leaping deer sign or as complex as variable message lighted signs that are set up and removed during seasonal animal movements. Several types of active warning systems sense the approach of an animal towards the roadway and signal a message to oncoming drivers; the one shown in the video is called the Roadway Animal Detection System although other systems with other names are also available.

3. Access roads (side roads) onto the highway are problematic for keeping animals off the highway because it is difficult to allow vehicles to cross through fencing without also enabling animals to pass through. What are two possible solutions mentioned in the video? Dual width cattle guards can be used for some species and in some geographic areas. Electric matting flush with the ground level can also divert animals from the openings in fencing that access roads provide.

4. Several other at-grade crossing solutions have been tested. Two types of approaches are used: change driver behavior or change wildlife behavior. Which of these approaches has proved to be most effective? In general, mitigation measures that target wildlife behavior (for example, reducing the ability of animals to cross highways with suitable fencing, or diverting wildlife to crossing structures) are more effective than attempts to modify driver behavior.

Video Part 5: Overpasses

A. Banff National Park, Canada

1. Why are overpasses considered suitable for animals that may not use enclosed structures such as bridges or culverts? Species that may not behaviorally tolerate dark or enclosed spaces are more likely to accept a structure that resembles their typical habitat. Overpasses can be designed to support elements of ecosystems such as soil and native plants. Because they are open to the sky, they also allow ambient temperature, sunlight, and moisture to occur on the surface.

2. Banff National Park in Canada is the location of the longest-running monitoring study of wildlife crossing structures in the world. For the large carnivores of the northern Rocky Mountains, what size width of wildlife overpass is currently deemed appropriate? For large carnivores, studies indicate a minimum width of 50 meters is appropriate.

3. How effective have Banff's wildlife crossing structures been to reduce ungulate/vehicle collisions, and all animal/vehicle collisions? Ungulate/vehicle collisions have been reduced 96%, and all wildlife/vehicle collisions have been reduced 80%. Smaller animals are more likely to breach the fencing than ungulates.

4. Reduction of vehicle-caused mortality is one measure of effectiveness of wildlife crossing structures. Another is the population-level dispersal benefits of structures, a much more difficult metric to measure. How is this being investigated in Banff National Park? Hair-snares with DNA testing are being used to investigate the relationships and movements of individuals across the highway.

Video Conclusion: Putting it Together (U.S. 93)

1. Why is it important to strategically design and place wildlife crossing structures with an integrated purpose? Maintaining healthy populations of wildlife and their ecosystems is more effectively accomplished using an integrated, strategic plan for ecological infrastructure than installing wildlife crossing structures or fencing independently.

2. The Montana US 93 case history provides a number of lessons on large scale integrated, interagency planning. These long term efforts over a number of years resulted in a change of paradigm on how to plan highways in areas with wildlife impacts. According to the video, what was a major change in the way of thinking on how to design a highway? The highway was designed to blend into the landscape to meet the needs of safety and traffic flow and also the wildlife important to the local stakeholders.

3. A feature of the long stretch of US 93 within the project area is its mix of wildlife crossing structures. Based on concepts shown earlier in this video, why would a mix of crossing structures provide ecological benefits? Different structures function best for a certain suite of species. Mixing the structure types ensures that all species' movement needs will be met.

4. Although the video does not identify all of the mitigation measures in the complex US 93 project, several key features are identified. What are these? The project sought to reduce vehicle-caused wildlife mortality and facilitate animal movement across the highway with a suite of wildlife crossing structures including several large underpasses, small/medium underpasses, extended bridges, one overpass, and associated fencing. Also included are escape ramps and access road modified cattle guards.

5. On the US 93 overpass, soil and vegetation will provide what benefits to wildlife? (Hint: consider concepts introduced earlier in the video as well.) Shade and hiding cover protection will be provided by larger trees. Based on earlier introduced concepts, soil and vegetation exposed to natural light and moisture will provide a small ecosystem for native species to use to cross the highway.

6. A 'green screen' is designed for the US 93 wildlife overpass. What is its purpose? The vegetation in the green screen will help to abate noise from the highway below, and reduce the visibility of the traffic. Along with the native vegetation, these features will help wildlife on the overpass to feel less intimidated in using the structure.

7. The US 93 project placed many of its wildlife passages in riparian areas. Why is it cost-effective to place wildlife crossing structures at drainages? Water conveyance structures

such as bridges or culverts would need to be placed at stream crossings regardless of their additional function as wildlife passages, so if they are also designed to pass wildlife the cost would be minimally extra.

8. The US 93 project included substantial monitoring, before and after construction. What are two post-construction monitoring methods used to determine the effectiveness of the wildlife crossing structures? Cameras at the wildlife crossing structures and sand beds to record tracks are two tools used to monitor the effectiveness of the structures.

9. US 93 offered many lessons learned for adaptive management. Overall, what is one key partnership lesson to be gained from their experience? Work through the planning, construction, and long term monitoring period with other disciplines such as engineers and hydrologists to improve future designs based on lessons learned.

10. The use of wildlife crossing structures is relatively new in North America, and the public is awakening to their use. What might be some public relations benefits of monitoring wildlife crossing structures? Camera images, for example, provide irrefutable evidence of animal use and can convince skeptics that animals do use them. Reduced carcass counts along a mitigated stretch of road can also show a cost-benefit to the public.

11. Can we have our cake (a fast, efficient human transportation system) and eat it too (allow wildlife to move across the landscape)? In the future, as we continue to build on the lessons learned in transportation ecology, we will be able to more fully integrate wildlife movement safely across highways.

Appendix 3: Additional Resources

Websites:

Wildlife Crossings Toolkit http://www.fs.fed.us/wildlifecrossings/

Wildlife and Roads http://www.wildlifeandroads.org/

Center for Transportation and the Environment http://cte.ncsu.edu/

Center for Environmental Excellence http://environment.transportation.org/

Context Sensitive Solutions FHWA, 2007 http://contextsensitivesolutions.org/

Federal Highway Administration Environmental pages
http://www.fhwa.dot.gov/environment/index.htm

US FWS Refuge Roads Program http://www.fws.gov/refuges/roads/

Caltrans Wildlife Crossings http://www.dot.ca.gov/hq/env/bio/wildlife_crossings/

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