Ventura County Planning Division

Roads and Biodiversity Project: Guidelines for Safe Wildlife Passage

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Southern California Association of Governments

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Table of Contents

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1 Guidelines Document Overview

1.1 Purpose

This document is designed to assist the Planning Division with conditioning discretionary land use entitlement permits with appropriate mitigations to minimize adverse impacts to wildlife movement corridors. Specifically, the document provides guidelines for designing roads and associated crossing structures to accommodate safe wildlife passage through the surrounding landscape. The recommendations provided herein are designed specifically for terrestrial animals and do not provide mitigation measures for fish. Projects that may impact fish, particularly steelhead trout, will require crossing structure mitigation, as dictated by the California Department of Fish and Game (CDFG) and the National Oceanic and Atmospheric Administration (NOAA). These requirements for fish passage must be included in addition to, and not in lieu of, the required design elements in this document.

According to the U.S. Department of Transportation's Federal Highway Administration, as of 1999, there are more than 3.9 million centerline miles of public roads that span the United States. Each day, an estimated 1 million animals are killed on roads, making roadkill the greatest direct human-caused source of wildlife mortality in the country (Forman 1998).

Road avoidance by species is an additional ecological impact. By impeding animal movement and restricting habitat connectivity, roads fragment habitats and causes isolation, which leads to problems such as inbreeding, resource depletion, reduction of biodiversity, and even extinction of wild populations (Soule 2001).

Efforts to mitigate negative wildlife-roadway interactions increasingly incorporate the use of modified culverts, pipes, and bridges as wildlife crossing structures. Most crossing structures are engineered to prevent roads from inhibiting the flow of water. However, with proper refinements and modifications these structures may also facilitate wildlife movement and habitat connectivity. Though efforts to utilize this type of mitigation have been researched and discussed since the mid 1970's, much remains to be done to synthesize and incorporate the current knowledge into planning policy.

The promotion of wildlife movement through crossing structures decreases wildlife mortality from vehicle collisions. It may also enhance species viability in areas where roads have fragmented habitat and restricted wildlife movement.

While the focus of this document is on the safety of wildlife, a compelling argument can be made that motorist injuries and deaths associated with wildlife collisions and accidents attributed to avoiding wildlife may be reduced. Documentation showed human fatalities and injuries were dramatically reduced in some Canadian national parks after the installation of wildlife crossing structures. No specific research was done on the number of injuries or deaths in Ventura County related to wildlife/motorist conflicts, but it logical to assume that if the number of conflicts can be reduced, so will the potential for injuries and deaths to humans.

1.2 Document Organization

The document sections are organized as follows:

- **Section 1:** Explains the document purpose and organization, and includes important definitions.
- **Section 2:** Details background information Ventura County policy authority to implement these guidelines, and outlines existing wildlife corridor connectivity in Ventura County.
- **Section 3:** Provides mitigation design elements to reduce the negative impact of roads on wildlife movement, including specific mitigation design elements for five wildlife Functional Groups of species, as well as considerations for multiples species mitigation.
- **Section 4:** Describes additional considerations for mitigation, including maintenance and monitoring, education and public outreach, and costs.
- **Section 5:** Provides a catalogue of various structure types and design features.

1.3 Definitions

Choke points
An area of narrow or impacted habitat that is constricted on opposite sides by development or has an otherwise tenuous connection between habitat patches.

Connectivity
The degree to which the landscape facilitates or impedes movement of organisms among habitat patches (Taylor and Goldingay 2003).

Crossing scenario
A collection of road design features intended to mitigate roadway impacts on wildlife, in addition to or in place of a crossing structure. Design features may include such elements as signage, speed control mechanisms, fencing, street lighting, and non-vegetated landscaping.

Crossing structure
A pipe, culvert, bridge underpass, or overpass which may be used by wildlife for passage over or under a roadway. Many of these crossing structures are intended to facilitate water flow.

Crossing substrate
The surface material composing the bottom of a crossing structure.

Functional Group
A group of species that tend to prefer similar crossing structure design characteristics, as shown below. This term is not a scientific classification system.

Functional Group	Examples of Species*
Large Mammal	Mountain Lion, Bobcat, Coyote, Deer
Medium Mammal	Fox, Opossum, Rabbit, Raccoon, Skunk
Small Mammal	Mouse, Rat, Squirrel
Upland Reptile	Lizard, Snake, Tortoise
Riparian Reptile/Amphibian	Frog, Toad, Turtle
Domestic	Cat, Dog, Cow, Horse, Human

*List not comprehensive

Landscape linkage
A large, regional arrangement of habitat (not necessarily linear or continuous) that enhances the movement of animals or the continuity of ecological processes at the landscape level (Bennett 2003). A landscape linkage may include numerous wildlife movement corridors.

Openness ratio
A characterization of crossing structures and defined by the equation: (Height x Width)/Length

Riparian habitat
Plant communities next to and affected by rivers, streams, lakes, or drainage ways (U.S. Fish and Wildlife Service/NWI 1997).

Wildlife movement corridor
Linear habitat whose primary wildlife function is to connect two or more significant habitat areas (Harris and Gallagher 1989).

2 Background

2.1 Ventura County Wildlife Movement Corridor Policies

There are a number of policies in separate County regulatory documents that support movement corridors and, by extension, the development of wildlife crossing structures. For example, the *Ventura County General Plan*, the overall guidance and vision for the County as set by its citizens and elected officials, specifically calls for the protection of wildlife movement corridors as stated in Goal 1.5.1:

Preserve and protect significant biological resources in Ventura County from incompatible land uses and development. Significant biological resources include endangered, threatened or rare species and habitats, wetland habitats, coastal habitats, wildlife migration corridors, and locally important species/communities.

Another policy document is the *Piru Area Plan*, which provides land use guidance specific to the north eastern portion of Ventura County. Two landscape linkages pass though this area. Goal 1.5.1 (2) is to:

Protect the Piru Creek wildlife migration corridor between the Los Padres National Forest on the north and the Santa Clara River and Oak Ridge Big Mountain habitat on the south.

These goals provide direction for the Ventura County Planning Division staff to review the impacts of discretionary land use entitlements on movement corridors. When the Planning Division receives discretionary land use entitlement applications, they review each project according to the California Environmental Quality Act (CEQA) guidelines for potential impacts to the environment, including movement corridors. The Planning Division and all other County agencies adhere to the *Ventura County Initial Study Assessment Guidelines* when assessing a project's potentially significant impacts to the environment. These Guidelines assist County staff with making mandatory findings of significance to the environment. CEQA Section 15065 (a) states that a project has significant impacts when:

The project has the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of an endangered, rare or threatened species, or eliminate important examples of the major periods of California history or prehistory.

The *Ventura County Initial Study Assessment Guidelines* (2000) include language regarding the importance and protection of significant biological resources, including movement corridors. They define a movement corridor as:

An area as defined by a qualified biologist, which experiences recurrent fish or wildlife movement and which is important to fish or wildlife species seeking to move from one habitat area to another.

The *Ventura County Initial Study Assessment Guidelines* provide the following threshold criterion, as determined by a qualified biologist, for impacting movement corridors:

A significant impact to a migration corridor would result if a project would substantially interfere with the use of said area by fish or wildlife. This could occur through elimination of native vegetation, erection of physical barriers or intimidation of fish or wildlife via introduction of noise, light, development or increased human presence.

2.2 Wildlife Corridor Connectivity within Ventura County

According to Conservation International, the California Floristic Province (which includes Ventura County) is one of the world's top 25 most biologically diverse and threatened regions. Thus, the loss of any landscape linkage in this region threatens some of the world's rarest and most precious biodiversity. Although Ventura County is highly fragmented by urbanization and extensive road networks, there are multiple landscape linkages and wildlife corridors connecting critical core habitats such as The Santa Monica Mountains to the south and The Los Padres National Forest to the north. Consequently, the remaining wildlife connectivity paths in Ventura County are a crucial last link to the Los Padres National Forest.

Preserving existing connectivity throughout the County is possible if key governmental entities (e.g. Ventura County, CALTRANS, and local cities) take modest steps to minimize road conflicts with wildlife. This can be achieved by creating strategically located and well designed crossing structures. In fragmented landscapes, connectivity can be maintained through:

1. A close spatial arrangement of small habitat patches serving as stepping-stones;
2. Corridors that link habitats like a network; and/or
3. Artificial measures such as wildlife passages (Bennett 2003).

Several studies have delineated a number of landscape linkages and wildlife movement corridors in Ventura County, identified some of the terrestrial species requiring connectivity, and documented the important role of crossing structure design features in facilitating wildlife movement.

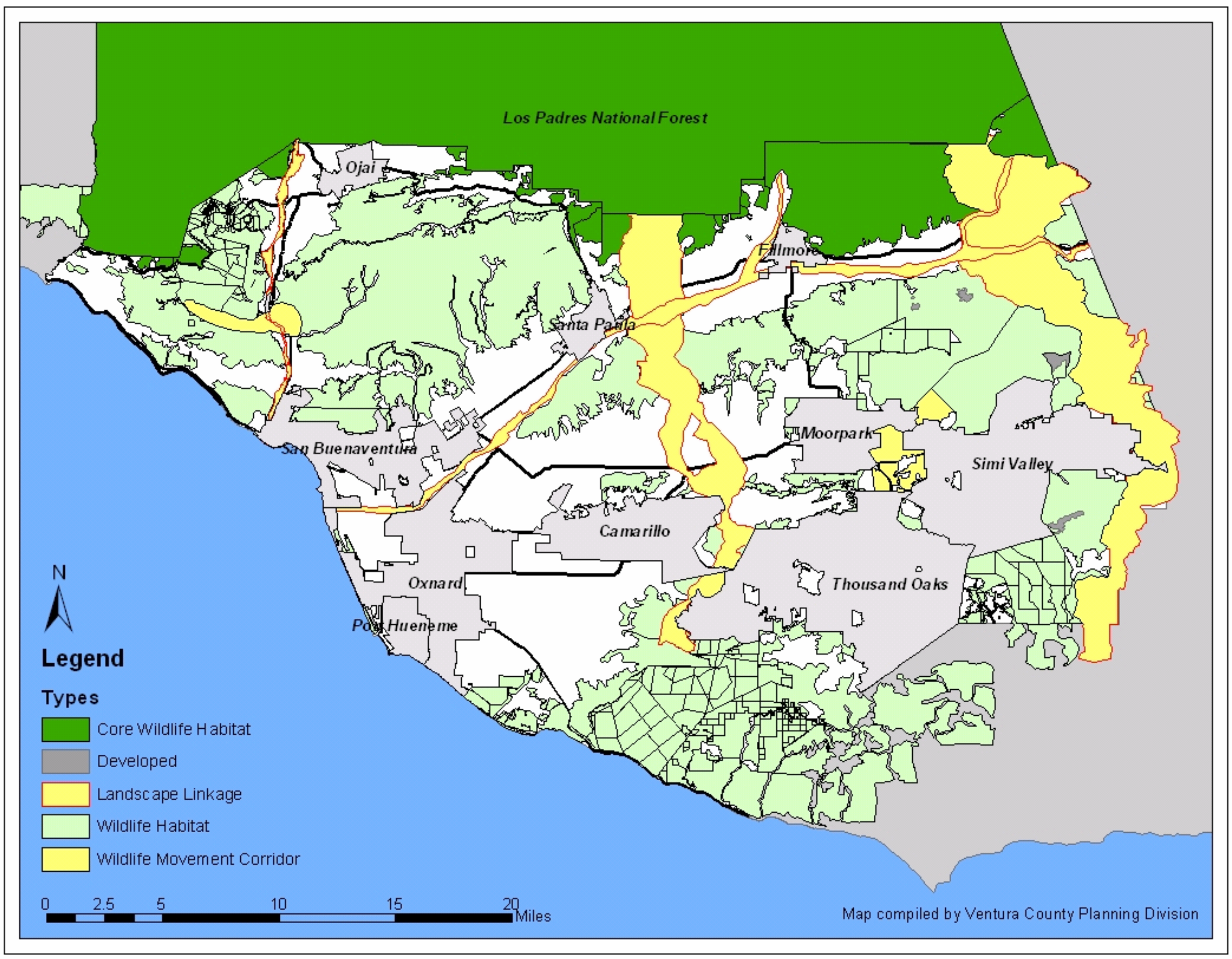
The South Coast Wildlands Project (SCWP), a non-profit organization, iniated the South Coast Missing Linkages Project in 2001. The resulting report, *Missing Linkages: Restoring Connectivity to the California Landscape* (Penrod et al. 2001), focused on 15 of the 69 critical landscape linkages most in need of protection in the South Coast region. Three of these 15 landscape linkages are located in Ventura County.

In 2002, the South Coast Wildlands Project and the UCSB Donald Bren School Group Project, *Wildlife Corridor Design and Implementation in the Southern Ventura County* (Casterline et al. 2003), initiated a Geographic Information System (GIS) analysis to address the wildlife connectivity needs and landscape linkage planning areas in Ventura County.

In 2003, a study entitled *Use of highway undercrossings by wildlife in southern California* (Ng et al. 2004) attempted to determine if wildlife utilizes underpasses and drainage culverts beneath highways for movement. The study area encompassed the eastern edge of Ventura County along three highways: US Highway 101, State Route 23, and US Highway 118. Each of these highways borders the Simi Hills on the south, west and north, respectively. Even though these crossings were not originally designed for wildlife movement, the study revealed that crossing structures in these locations were used by various species, providing important, safe passage for animals. The study also identified the importance of suitable habitat and fencing.

The map below (Figure 2.1) represents a collaboration of multiple organizations to identify some of the locations landscape linkages and wildlife movement corridors in Ventura County. This map does not comprehensively identify all wildlife connectivity areas of the County.

Figure 2.1: Landscape Linkages, Wildlife Movement Corridors, and remaining wildlife habitat in Ventura (Ventura County, 2005)



2.3 Wildlife Movement Corridor Assessment

As required by the *Ventura County Initial Study Assessment Guidelines*, a qualified wildlife biologist will assess the proposed project area to determine if a wildlife movement corridor(s) exists within the project site and/or the surrounding area, and if the project will adversely impact the corridor(s). To function as a wildlife movement corridor an area must (Ogden 1992):

1. Link two or more patches of isolated habitat;
2. Conduct animals to areas of suitable habitat without excessive risk of directing them into a “mortality sink” – an unsuitable area where the death rate is higher than the rate of replacement; and
3. Allow individuals of the target species to use the corridor frequently enough to facilitate demographic and genetic exchange between populations.

To date, wildlife corridors in Ventura County have been identified by consulting with local wildlife biologists and using least cost path modeling and suitability analysis. Several groups have been involved in this process including the South Coast Wildlands Project (SCWP), the Donald Bren School of Environmental Science and Management, Conception Coast Project, the National Park Service, the California Department of Transportation, universities, and biological consulting firms working in Ventura County.

Currently, a wildlife movement corridor rapid identification tool is being developed. This tool will be used during the Initial Study Assessment and will assist consulting biologists in determining if the project will impact a corridor and to what degree.

If a wildlife movement corridor is present and the project will adversely impact the corridor, mitigation measures must be implemented or changes to the project design must be made. These mitigation measures may include, but are not limited to, the design elements listed in these guidelines.

The recommendations provided in this document are based on the assumption that mitigations will be implemented in the most appropriate and desirable location within the impacted wildlife movement corridor, as determined by a qualified wildlife biologist and through consultation with appropriate regulatory agencies. Proper placement of wildlife crossing structures is one of the most important considerations for successful mitigation. Most studies indicate that placing the crossing structure near traditional movement routes will increase effectiveness. Studies conducted in Florida determined that structures placed without regard to traditional movement paths failed (Hartmann 2003).

3 Mitigation Guidelines

The following guidelines for mitigation design shall be consulted once it is determined that a project will impact a wildlife movement corridor.

3.1 Summary of Design Elements for Successful Mitigation

Wildlife crossing structures may consist of many shapes and sizes to accommodate the variety of species that inhabit an area. Though each species has different specific needs, there are some required design elements that serve to make road crossings more permeable for all species (Figure 3.1). Specific design elements for successful crossing mitigation are detailed in Section 3.3.

Design elements **necessary** for successful mitigation:

- Suitable Habitat
- Funneling/Fencing
- Wildlife Accessibility
- Minimal Human Activity

Additional **highly recommended** design elements:

- Traffic Control Measures
- Appropriate Road Design Elements
- Appropriate Structure Design (Shape, Size, Noise, Temperature, Light, Moisture)

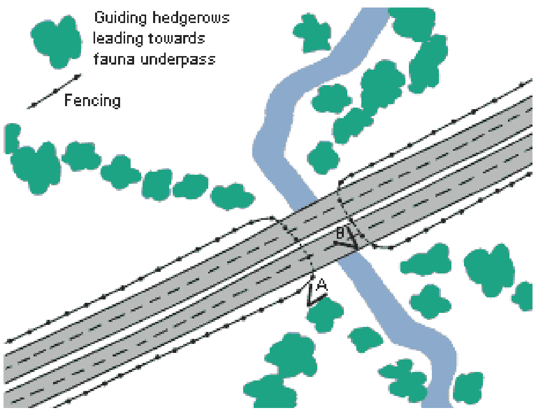


Figure 3.1: Example of a crossing scenario

Not all mitigation guidelines apply to all projects and should be applied to projects on a case-by-case basis under the discretion of the consulting and in-house biologists and planners. In many cases mitigation will be required for multiple Functional Groups. In these instances, designing a cross-Functional Group structure will require the discretion and innovation of both planners and biologists.

The success of a crossing structure can only be assessed through careful and consistent monitoring (Hardy et al. 2003). It may take months or even years to fully asses the effectiveness of a crossing structure. Monitoring and maintenance plans should be prepared to ensure that mitigation systems continue to function over time. Maintenance of a crossing structure should include clearing debris or other impediments to movement through the structure, maintaining the surrounding fencing, vegetation, and habitat, as well as ensuring overall structural integrity.

For further discussion on development and implementation of maintenance and monitoring programs, please refer to Section 4: Additional Mitigation Considerations.

Table 3.1: Design Elements for Wildlife Functional Groups

Scale of Effectiveness

Minimum Required	Best	Non Applicable
■	□	×

Mitigation Design Elements	Functional Group				
	Large Mammals	Medium Mammals	Small Mammals	Amphibians/ Riparian Reptiles	Upland Reptiles
1. Maintain Suitable Habitat	■	■	■	■	■
2. Minimize Human Activity	■	■	■	■	■
3. Funneling/Fencing	■	■	■	■	■
4. Accessibility	■	■	■	■	■
5. Vehicle Speed Reduction	□	□	□	□	□
6. Wildlife Crossing Signs	□	□	□	□	□
7. Non-Vegetated Roadway	□	□	□	□	□
8. Noise Mitigation	□	□	□	□	□
9. Street Lighting	□	□	□	□	□
10. Appropriate Structure Type	■	■	■	■	■
Pipe culvert	■	■	□	□	□
Box culvert	■	■	□	□	□
Bridge Underpass	□	□	■	■	■
Overpass	□	□	■	■	■
11.Vegetated Structure Entrance	□	□	■	■	■
12. Structure height	■	■	■	■	■
13. Structure Openness	■	■	×	×	×
14. Field of view	■	×	×	×	×
15. Ledges	□	□	□	□	□
16. Consistent Internal Habitat	□	□	□	□	□
Natural substrate bottom	□	□	□	□	□
Natural lighting	□	□	□	□	□
Natural temperature	□	□	□	□	□
Reduced noise	□	□	□	□	□
Internal cover	×	□	□	□	□
Moisture	×	×	×	■	×
17. High frequency of placement	×	×	■	■	■
Additional Considerations					
Education and Public Outreach	□	□	□	□	□
Maintenance	■	■	■	■	■
Monitoring	■	■	■	■	■

3.2 Summary of Wildlife Functional Groups

Individual species have different needs regarding crossing structure features. In particular, physical characteristics such as size and substrate will be very important to some species, but irrelevant to others. For example, research suggests that a moist substrate is essential for amphibian use, while large mammals are generally indifferent to the substrate surface. To accommodate these varying needs, specific design elements are provided for five different wildlife Functional Groups.

Functional Groups are species which tend to prefer similar crossing structure characteristics. Each project should be scrutinized by a consulting biologist to identify the specific species likely to be present in the project area, and to determine the most appropriate mitigation actions. Table 3.1 summarizes the minimum required and best mitigation design elements for each wildlife Functional Group, which are detailed further in Section 3.3. A summary of each wildlife Functional Group is provided in the following sections.

3.2.1 Large Mammals

The Large Mammals Functional Group includes species such as mountain lion, deer, bear, coyote, and bobcat. Large mammals generally stand at least 1.5 ft at the shoulder, and have a length of at least 2 ft (not including tail). Large mammals are especially impacted by habitat fragmentation because of their need for significant home ranges and slow population growth rates, which results in lower population densities. Large mammals typically prefer large, open crossing structures, such as bridge underpasses and box culverts (Singer and Doherty 1985, Foster and Humphrey 1995, Reed et al. 1981, Clevenger and Waltho 2005, Jacobson 2002, Ng et al. 2004, Barnum 1999, Cain et al. 2003). This conclusion is also supported by local field survey results.

Figure 3.2: Large Mammals passing through box culverts

3.2.2 Medium Mammals

The Medium Mammals Functional Group includes species such as opossum, skunk, raccoon, fox, and rabbit. Medium mammals generally range in height between 6 inches to 1.5 ft at the shoulder, and range from 16 inches to 2 feet in length. Although local field survey results show that medium mammals use a mix of crossing structure types, studies suggest that medium mammals may tend to prefer box or pipe culverts (Clevenger et al. 2003, Forman and Alexander 1998, Taylor and Goldingay 2003).

3.2.3 Small Mammals

The Small Mammals Functional Group includes species such as squirrels, rats, voles, and mice. Small mammals are generally a few inches high and up to 16 inches long. Scientific studies and local field survey results show that small mammals have a preference for using box and pipe culverts.

3.2.4 Amphibians and Riparian Reptiles

The Amphibians/Riparian Reptiles Functional Group includes species which prefer wet or moist environments such as frogs, toads, salamanders, turtles and some species of snakes. Although amphibians/riparian reptiles have been known to use a mix of crossing structure types, they tend to prefer small box or pipe culverts with moist substrates.

Figure 3.3: Salamanders exiting an amphibian crossing

3.2.5 Upland Reptiles

The Upland Reptiles Functional Group includes classes of species which prefer dry, sunny environments such as lizards, tortoises, and some species of snakes. Upland reptiles have been known to use a mix of crossing structure types, including bridge underpasses, box culverts, and dry pipes. However, local field survey results indicate a preference for box culverts to either bridge underpasses or pipes.

3.3 Mitigation Design Elements

DE1. Maintain Suitable Habitat

Suitable habitat must be present on both sides of the road in the proximity of the crossing structure. If the habitat is degraded in the location where the crossing structure is planned, the habitat should be restored to its natural condition. If the construction of the project will degrade the area, it should be returned to its original condition. Natural vegetation should connect the larger habitat patch with the opening of the structure. This can be used as a mechanism to guide animals towards the structure. The natural habitat of the wildlife corridor and vegetation at the entrance of the crossing structure must be maintained.

Several studies suggest that natural vegetation surrounding and leading up to the entrance of a crossing structure is important for wildlife usage (Smith 2003, Ng et al. 2004, Clevenger et al. 2001, Clevenger et al. 2003). Natural vegetation provides continuity of the habitat and may encourage animals to approach a crossing structure, while abrupt changes in the vegetation may discourage animals from approaching.

DE2. Minimize Human Activity

Minimize human activity by relocating human foot trails and restricting human use of underpasses. Restrict access to corridor and crossing structures between dusk and dawn as this will be a time of high animal activity. Prohibit the presence of pets (leashed or unleashed) in the structure and within the corridor at all times. Post signs to indicate the existence of wildlife movement corridor and educate residents in the area regarding the purpose of restrictions of the movement corridor.

Crossing structures may be ineffective if human activity is not controlled (Clevenger and Waltho 2000). By placing structures away from areas that are frequently used by humans and restricting human use of passages, it is likely that the structures will be more appealing to wildlife (Hartmann 2003).

DE3. Funneling/Fencing

Wildlife funneling, typically using fences, is necessary for effective crossing structures. Fencing will guide animals towards a structure entrance and deter animals from approaching a roadway (Bissonette and Hammer 2000, Cain et al. 2003, Clevenger and Waltho 2003, Dodd et al. 2004, Feldhamer et al. 1986, Falk et al. 1978, Taylor and Goldingay 2003). Roadkill can be dramatically reduced on roadways that have both fencing and crossing structures. In Wyoming, road kills of mule deer have been reduced by 90% while there has been a 97% decrease in the number of elk killed in Banff National Park in Canada (Hartmann 2003). In Paynes Prairie State Preserve, Florida, roadkill mortality of all animals (excluding hylid treefrogs, which easily trespass the barrier system) was reduced by 93.5% after construction of a barrier wall-culvert system (Dodd et al. 2004).

Fencing is beneficial only when used in conjunction with an appropriate crossing structure. In fact, extensive stretches of fencing may actually contribute to fragmentation and isolation. In addition, studies suggest that predators have learned to use fencing as a trapping mechanism (Hartmann 2003). In Banff National Park, coyotes have been observed running bighorn sheep into the fence along the Trans-Canada Highway. In other areas, wolves and cougars have been documented herding deer up against highway fencing (Foster and Humphrey 1995). For these reasons, fencing should be used primarily as a means to funnel animals towards and into an appropriate crossing structure.

Figure 3.4: Fine mesh fence for small animals

Fence height and material are important considerations. Fence height may range from 1.5 ft for smaller animals to a minimum of 8 ft for large mammals. Fencing material should not be penetrable by the species of interest and be constructed of chain link, wood, galvanized tin, aluminum flashing, plastic, vinyl, concrete, or a very fine mesh (Figure 3.4). To prevent animals from digging under it, fencing should be buried to a depth appropriate for the type of species in the area (Jacobson 2002).

Figure 3.5: Lipped concrete wall

A preventative fence top such as barbed wire, lipped wall (Figure 3.5), or overhang is recommended to discourage animals from climbing over the fence. Some animals have been observed climbing vegetation growing along funneling mechanisms despite the presence of preventative fence tops (Dodd et al. 2004). Routinely removing or trimming back vegetation acting as “natural ladders” decreases this risk. Though applying herbicide along the funneling/fencing mechanism may temporarily resolve the problem, vegetation must be regularly cleared, particularly during the growing season.

The extent of fencing is another important factor. Generally speaking, fencing should extend far enough on either side of a structure to reasonably guide the species functional group of interest to the crossing structure and away from the road. For large animals, this could be the entire length of the parcel boundary, while smaller animals would likely require less. It may also be appropriate to fence up to a natural break in an animal's ability to traverse the landscape, such as a steep slope or habitat edge. When extensive fencing is utilized on only one side of a crossing structure, one-way gates or escape ramps (Figure 3.6) should be included to prevent animals from being trapped on the road (Bissonette and Hammer 2000, Danielson and Hubbard 1998, Conover 2002).

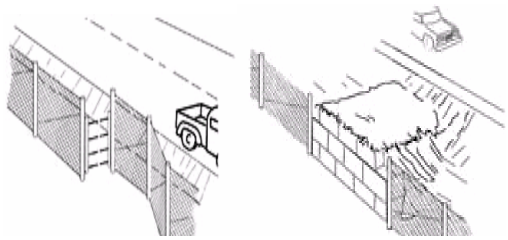


Figure 3.6: One-way gate and escape ramp

Table 3.2 Functional Group Specifics for Fencing Application

Functional Group	Fence Height	Fence Material	Buried	Preventative Top
Large Mammals	8 ft	Chain Link	Yes	Barbed Wire
Medium Mammals	3-6 ft	Chain Link	Yes	Barbed Wire
Small Mammals	3-4 ft	Fine Mesh	Yes	Overhang
Amphibians/ Riparian Reptiles	1.5 to 2.5 ft	Galvanized Tin, Aluminum Flashing, Plastic, Vinyl, Concrete, Very Fine Mesh	Yes	Overhang/ Lipped Wall
Upland Reptiles	1.5 to 2.5 ft	Galvanized Tin, Aluminum Flashing, Plastic, Vinyl, Concrete, Very Fine Mesh	Yes	Overhang/ Lipped Wall

Appropriate funneling mechanisms vary widely across functional groups. To accommodate several species, a fine mesh fence or flashing is often applied to the bottom one-third to one-half of a taller chain link fence to prevent both small and large animals from accessing the road right-of-way (Figure 3.7). Additional measures include combining fencing for large mammals along the road with lipped walls for amphibians and reptiles along the banks for the structure entrance (Figure 3.8).

Figure 3.7: Wide mesh chain link fence for large mammals, with a fine mesh fence border for small mammals and amphibians

Figure 3.8: Arch culvert with fence for large mammals and lipped wall for amphibians

DE4. Accessibility

A crossing structure must be accessible to the species that will potentially use it. Avoid steep slopes leading to the structure. The structure entrance should be flush with the ground and should be large enough to accommodate the target species. An example of an inaccessible structure is shown in Figure 3.9.

Figure 3.9: Perched pipe

Figure 3.10: Culvert with standing

Incorporate measures to minimize erosion around the structure entrances into the structure design. If a crossing structure is used to convey water as well as to facilitate animal movement, it should be designed to prevent water from pooling inside or at the opening of the structure. Such standing water will render the structure less accessible to many animals (Figure 3.10).

DE5. Vehicle Speed Reduction

Reducing traffic speed can greatly reduce wildlife mortality from vehicle collisions and enhance driver safety. Vehicle speed reduction may be achieved through reduced speed limit signs, speed humps/cushions, rumble strips, and speed feedback signs.

DE6. Wildlife Crossing Signs

Wildlife crossing signs inform the public of the potential presence of sensitive, slow moving species on the roadway (Figure 3.11). This may encourage drivers to slow down and be more observant of the roadway in the area, thereby reducing mortality from animal-vehicle collisions.

Figure 3.11: Wildlife crossing sign

DE7. Non-Vegetated Roadway

Vegetation along a roadway may be a food source or may provide cover from predators and may encourage animals to approach the road. Therefore, the immediate roadside should have minimal vegetation to discourage animals from approaching the roadway.

DE8. Noise Mitigation

Traffic noise should be reduced within 50 feet on either side of the structure. A noise level of 45 db or less in the vicinity of the crossing structure has been recommended (Rincon Consultants 2002). Traffic noise may discourage animals from approaching a structure, specifically animals that are sensitive to noise and/or human presence. When choosing a material for a pipe or box culvert, consideration should be given to materials that reduce noise transmission. Examples of noise mitigation measures include sound walls, dense vegetation at the structure entrance, and a smooth roadway to reduce noise from friction. Smoother, quieter road surfaces should extend an appropriate distance on either side of the crossing. Traffic noise mitigation is especially important on more heavily trafficked roads.

DE9. Street Lighting

To encourage animals to approach a structure, it is recommended that street lighting in proximity to the entrance should be removed or directed away from structure entrances (Reed et al. 1981, Hartmann 2003, Jackson 2000).the road area should be unlit and resemble ambient conditions. The darker the structure appears compared to the surrounding area, the more appealing it will be to an animal.

Street lighting or headlight reflectors are recommended along the roadway at an appropriate distance on either side of the structure. Headlight reflectors, placed along the roadside, are designed to reflect the light from on-coming headlights into the surrounding landscape, which may deter animals from approaching the roadway. If the surrounding area is artificially lit, the animals may be drawn to the darker area of the structure entrance.

DE10. Appropriate Structure Type

There are four main types of crossing structures:

- Pipe culvert
- Box culvert
- Underpass
- Wildlife overpass

Many factors must be considered when determining which crossing structure is most appropriate for mitigation, including road type, surrounding land use and hydrology, and which species may use the structure. In general, larger structures such as underpasses and wildlife overpasses are most appropriate for medium and large mammals, while smaller structures such as pipe or box culverts are more appropriate for small mammals, reptiles and amphibians. The four main types of crossing structures are described below.

Pipe Culverts

Pipe culverts (Figure 3.12) are made of smooth steel, corrugated metal, or concrete material. Their primary purpose is to convey water under roads, though a variety of wildlife has been observed using them as passageways. They typically range in size from 1ft to 6 ft in diameter and are the least expensive wildlife crossing structure.

Figure 3.12: Pipe culvert

Box Culverts

Figure 3.13: Box Culvert

Box culverts (Figure 3.13), used to transmit water during brief periods of runoff, are usually dry for much of the year and are used by a variety of wildlife (Rodriguez et al. 1996, Yanes et al. 1995, Clevenger and Waltho 2000). Unlike a bridge, they have an artificial floor such as concrete, though this floor may be covered by sediment and/or vegetation. Box culverts generally provide more room for wildlife passage than large pipes. Though they are less expensive than expanded bridges, they may also be less effective than bridges (Beier 1995).

Underpass

Figure 3.14: Bridge underpass

When roads cross rivers and streams via a bridge, the resulting underpasses can provide a passageway for many wildlife species that may use stream corridors for travel (Figure 3.14). These structures are generally large areas that provide relatively unconfined passage for wildlife and water. Underpasses with open medians make the structure appear larger and more open, which is preferred by larger animals, and provide a certain amount of intermediate habitat for small mammals, reptiles, and amphibians. However, open median designs are much noisier than continuous bridges and may be less suitable for species that are sensitive to human disturbance (Jackson and Griffin 2000). Human activity within or around underpasses may significantly reduce their effectiveness for wildlife (Clevenger and Waltho 2000). While less expensive than overpasses, wildlife underpasses are relatively costly compared to box or pipe culverts.

Wildlife Overpass

Figure 3.15: Bridge overpass

Wildlife overpasses (Figure 3.15) have been constructed in Europe, the U.S., and Canada. The most effective overpasses range in width from 165 ft wide on each end narrowing to 25–115 ft in the center, to structures up to 650 ft wide. Soil on these overpasses, ranging in depth from 1.5 to 7 ft, allows for the growth of herbaceous vegetation, shrubs, and small trees. Some contain small ponds fed by rain water. Wildlife overpasses appear to accommodate more species of wildlife that do underpasses. Primary advantages relative to underpasses are that they are less confining, quieter, and can maintain ambient conditions of rainfall, temperature, and light. Further, overpasses can serve both as passageways for wildlife and habitat for small animals such as reptiles, amphibians, and small mammals. By providing consitent habitat, overpasses may provide a feasible alternative for various species to cross highways, especially small animals. The major drawback is that they are expensive (up to $2 million dollars for a four lane divided highway (O'Malley 2004)). As a result, their use is usually reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitat (Jackson and Griffin 2000).

DE11. Vegetated Structure Entrance

In general, the crossing structure entrance should have dense vegetation near the entrance to provide cover for animals. Further, this cover should extend from the main patch of habitat to the entrance of the structure, in order to provide smaller animals with constant protection from predators. Natural vegetation should surround the approach and entrance of a crossing structure and must provide connectivity from the larger habitat patch to the structure entrance (Ng et al. 2004, Smith 2003, Clevenger et al. 2001, Clevenger et al. 2003).

Vegetation surrounding the approach to the structure is an important consideration when designing for multiple Functional Groups. While natural vegetation is important to maintain habitat continuity, the type of vegetation can play an important role in structure use. Most small mammals, amphibians, and reptiles will prefer low stature cover in the form of vegetation, rocks, and logs to protect them from predators. Medium and large mammals that are prey species (rabbits, deer) may be wary of using structures with extensive vegetation where predators can hide. Eliminating potential predator ambush opportunities, while providing good visibility for medium and large mammal prey species, will encourage their use of a crossing structure (Jackson and Griffin 2000).

DE12. Appropriate Structure Height

Minimum structure heights for each Functional Group are as follows:

- Large Mammals: 6 ft
- Medium Mammals: 3 ft
- Small Mammals: 1 ft
- Amphibian/Riparian Reptiles: 1 ft
- Upland reptiles: 1 ft

DE13. Structure Openness

The openness ratio of a crossing structure opening (Openness Ratio = (Height x Width)/Length) is a function of structure length, which corresponds to the width of the roadway.

The minimum openness ratios for structures are as follows:

- Large Mammals: 0.75
- Medium Mammals: 0.4

The cross-sectional area of the structure entrance should become larger as the length of the structure increases. Therefore, for large and medium mammals, structural dimensions are determined by road width and appropriate structure openness ratio. Recommended cross-sectional areas are provided in Table 3.3 and 3.4 below for different sized road ways.

Table 3.3: Recommended Structure Cross-Sectional Areas (CSA) for Large Mammals

Road Type	Approx. Road Width	Recommended CSA
2-lane road	30 ft	22 sq ft
4-lane road	60 ft	45 sq ft
6-lane road	>75 ft	60 sq ft

Table3. 4: Recommended Structure Cross-Sectional Areas (CSA) for Medium Mammals

Road Type	Approx. Road Width	Recommended CSA
2-lane road	30 ft	12 sq ft
4-lane road	60 ft	24 sq ft
6-lane road	>75 ft	30 sq ft

While openness is not as important for small mammals or amphibians and reptiles, tend to prefer smaller cross-sectional areas more appealing for these Functional Groups. A cross-sectional area of 2 to 9 sq ft for the structure entrance is highly recommended (Clevenger et al. 2001, Goosem et al.2001).

DE14. Open Field of View

An open field of view must exist in order for large mammals to use a crossing structure (Jackson 2000, Jacobson 2002, Foster and Humphrey 1995). A large mammal is more to likely pass through a crossing structure if suitable habitat is clearly visible on the other side (Figure 3.16). The need for an open field of view also correlates with the preference for a large openness ratio.

Figure 3.16: Underpass with open field of view for large mammals

DE15. Ledges

Elevated concrete ledges (Figure 3.17), or “catwalks”, lining one or both interior walls of the structure may allow wildlife to pass through a crossing structure when it is filled with water (Barnum 1999, Cain et al. 2003, Forman and Alexander 1998, Hartmann 2003, Jacobson 2002). A ledge should line the entire length of the interior, extend to a height above peak water flow, and be covered with natural substrate consistent with the external habitat. Interior ledges must be wide enough to accommodate species of concern.

Figure 3.17: Elevated ledge with vegetation

Incorporation of ledges is recommended for structures that facilitate continuous or occasionally heavy flow of water. Alternatively, if the dimensions of the crossing structure are too narrow to accommodate an interior ledge, an additional elevated culvert may be incorporated to allow animals to pass under a road when the existing structure is filled with water.

DE16. Consistent Internal Habitat

The following design elements are intended to create a natural environment within a crossing structure. If the internal habitat of a structure is relatively consistent with the surrounding habitat, then animals may be more likely to pass through a crossing structure.

Natural Substrate

It is recommended that the crossing structure incorporates a bottom lined with natural substrata that is consistent with the external habitat surrounding either side of the structure and appropriate for the Functional Group(s) of interest. While the literature and field observations do not necessarily demonstrate that a natural substrate bottom is essential for animals to use a crossing structure, some studies do suggest that providing a natural substrate throughout the entire length of a crossing structure will maintain habitat continuity and, therefore, encourage animals to pass through the structure (Yanes et al. 1995, Jackson 2000, Hartmann 2003).

Natural Lighting

Artificial light deters animals from using a crossing structure (Reed et al. 1981, Jackson 2000, Hartmann 2003). A crossing structure may look more appealing to animals if ambient lighting conditions are maintained inside the structure. For instance, a larger cross-sectional area entrance, ensuring a larger openness ratio or the use of open medians can achieve natural lighting that will appeal to large mammals. Conversely, a smaller cross-sectional area entrance or low stature vegetation, such as stumps, rocks, or shrubs, will achieve a darker environment more likely to be favored by small mammals, amphibians, and reptiles. Skylights or slotted drains may be incorporated into the design to allow natural light to enter a dark structure.

Natural Temperature

Animals will be more willing to use a structure if the internal temperature is consistent with the external temperature (Jackson 2000). This can be achieved by including slotted grates above the structure or designing crossing structures to be larger and more open. However, slotted grates may increase traffic noise inside the structure if it is located below a heavily trafficked roadway. In addition, larger structures may be uninviting to smaller animals that prefer smaller structures.

Reduced Noise

Human presence deters animals from using crossing structures (Clevenger and Waltho 2000, Clevenger and Waltho 2005, Jackson 2000, Hartmann 2003, Smith 2003). Many animals are sensitive to noise, especially from traffic and other human noise disturbance associated with roads (Jackson 2000, Hartmann 2003). To reduce noise inside a crossing structure, consideration should be given to materials that reduce noise transmission. For example, the selection of concrete or plastic materials may be less noisy than metal materials. Dense vegetation adjacent to the structure entrance that does not impede water flow, or sound walls on the road shoulder in proximity of the structure, may also reduce exposure to noise.

Interior Cover

Small mammals, amphibians and reptiles usually prefer some type of low stature cover on the interior of the structure to function as protection from predators (Smith 2003, Hartmann 2003, Hunt et al. 1987). Typically, they will pass through a structure along the interior wall because it may appear more protected. Vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, will provide small animals with cover from predators, encouraging them to pass through a structure.

Moisture

Amphibians and riparian reptiles use cover to protect themselves from the drying heat of the sun and predators. These animals will readily use a crossing structure with a natural substrate if it has adequate moisture and hiding cover that functions as protection. Low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, will provide amphibians and riparian reptiles with cover, encouraging them to pass through a structure.

Because moisture is an important consideration for amphibians and riparian reptiles, a moist substrate is a vital feature of a suitable crossing structure. However, standing water prevents most species from utilizing a structure. Culverts that accommodate amphibians and riparian reptiles must maintain moist travel conditions, without creating standing water or flooded conditions. Therefore, proper drainage of the crossing structure is another important consideration. In larger culverts, maintaining or replicating stream bed conditions facilitates use by amphibians and riparian reptiles (Jackson and Griffin 2000). Slotted drain culverts are successful in maintaining proper moisture and drainage, while also providing ambient light (Figure 3.18). Ongoing maintenance of these structures to clear debris and maintain openness is essential.

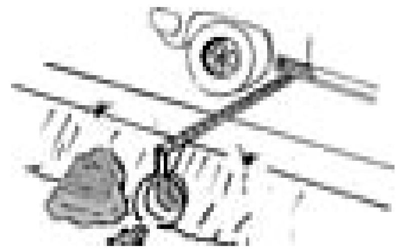


Figure 3.18: Slotted drain culvert

DE17. Frequent Structure Placement

Travel distance between structures may influence structure use by medium mammals, for even relatively mobile species.

For projects that span over 0.5 miles of roadway, structures frequency should generally be as follows:

- **Medium Mammals**: 500 to 1,000 ft
- **Small Mammals**: 150 - 300 ft
- Amphibian/Riparian Reptiles: 150 - 300 ft
- Upland reptiles: 150 - 300 ft

3.4 Considerations for Multiple Functional Groups

While considering the variety of internal habitats preferred by different Functional Groups, it is not surprising that the specific design elements for different species may be contradictory. For example, open-top culverts may provide favorable lighting, temperature, and moisture conditions for amphibians but may be too noisy for some mammals. Structures can be designed to facilitate multiple Functional Groups by incorporating design elements preferred by each. For instance, a large bridge underpass designed to facilitate the movement of large mammals could also accommodate small mammals by incorporating low stature vegetation or other naturally occurring substrate, such as tree stumps, hollow logs, or rocks, in the interior of the structure. Similarly, a structure could accommodate small mammals, amphibians, and riparian reptiles by maintaining moisture in the bottom of the structure but also providing a dry elevated ledge.

Alternatively, multiple structures in the same area could be incorporated to accommodate several Functional Groups. A large box culvert that accommodates large and medium mammals could be flanked by smaller pipes on either side to accommodate smaller mammals, amphibians, and reptiles. This option addresses the need for different light, noise and moisture needs particularly well.

Ultimately, there is no simple single approach to mitigation. A variety of alternatives can and should be explored. A structure that incorporates as many mitigation design elements as possible will most likely be the most successful at accommodating wildlife movement.

4 Additional Mitigation Considerations

4.1 Public Education

Figure 4.1: Wildlife corridor sign

An additional element of a successful mitigation strategy is public education. Educating the local community about sensitive species in the area provides citizens with a heightened awareness of the impacts of roads on wildlife. For instance, a person driving on a road which crosses a wildlife corridor may be more likely to respond to wildlife signs or traffic control measures if he or she is educated about the sensitive wildlife in the area. The importance of public education in mitigating wildlife-roadway conflicts should not be underestimated and some form of public education is strongly recommended.

Forms of public education and outreach may include, but are not limited to:

- Adopt-a-corridor program
- Public educational seminars
- Mail flyers
- Local cable access TV commercials
- Wildlife corridor signs (Figure 4.1)
- Informative brochures
- Volunteer programs

4.2 Maintenance and Monitoring

Prior to approval of projects that require wildlife corridor mitigation, a project-specific maintenance and monitoring program must be developed. The party or parties responsible for maintaining and/or monitoring the proposed mitigation should be specifically identified.

The maintenance and monitoring program must include the following elements:

- Description of party/parties responsible for maintenance
- Maintenance and monitoring schedule, including time frame and frequency
- Maintenance procedures
- Monitoring approach and procedures

Structure use can be monitored with a variety of tools and techniques such as gypsum track plates, motion-detection cameras, and trap-and-release. The approach to structure monitoring will depend on the type of crossing structure, as well as the targeted species. Individual species behavior and spatial and temporal movement patterns will influence the monitoring technique and frequency of observation. A qualified biologist should be consulted to develop a monitoring program and determine an appropriate monitoring frequency and time frame. For best results, long-term monitoring must be conducted to fully assess structure use and effectiveness (Barnum 1999, Hardy et al. 2003).

The frequency and extent of maintenance will depend upon the type, size, and functionality of the crossing structure. For instance, smaller structures or structures that also facilitate water flow may require more frequent maintenance than a large, relatively dry bridge underpass. During periods of heavy rain, water flow through culverts typically increases dramatically, causing silt accumulations and erosion to occur. A heavy build-up of silt could eventually diminish the area available for wildlife passage (Dodd et al. 2004), and erosion can greatly reduce accessibility, especially for smaller animals. Furthermore, soil erosion occurring in the immediate proximity of the crossing structure can reduce wildlife accessibility. Extensive erosion often results in perched structures that are unsuitable for wildlife passage and deep gullies that destroy private property. Ongoing maintenance efforts should include filling eroded landscape to match the grade of the surrounding habitat and ensure wildlife accessibility into the crossing structure.

Funneling/fencing mechanisms will require regular maintenance because animals are likely to attempt to dig under barriers and take advantage of holes. In addition, vegetation immediately adjacent to the funneling/fencing mechanism that may act as natural ladders for an animal to climb over must be removed regularly, particularly during the growing season.

4.3 Cost

Designing roads for safe wildlife passage is necessary to reduce wildlife-vehicle collisions and maintain species biodiversity. Although the cost of mitigation can be substantial, the cost of avoiding mitigation can potentially result in even greater long-term costs. Wildlife-vehicle collisions constitute an estimated 4.6% of all U.S. automobile accidents, with more than 1.5 million accidents a year, 150 deaths, and $1.1 billion in vehicle damage (Perrin and Disegni 2003). Individual motorists usually pay at least $2,000 in vehicle repair every time they hit a deer (U.S. Department of Transportation Federal Highway Administration 2000). Furthermore, the benefits of reducing wildlife mortality and maintaining species biodiversity serve many interests including tourism and recreation.

An important consideration in designing appropriate mitigations is short-term versus long-term costs. Short-term costs include the initial installation or modification of a structure, fencing, or the planting of native vegetation. Long-term costs include maintenance and monitoring. Some structure designs may require greater up front costs that reduce the need for long-term maintenance (erosion reduction). The lifetime cost of alternative crossing structures must be considered to accurately assess the total cost of mitigation and the optimal structure design.

Wildlife passage construction requires creative thinking and innovative engineering design to develop elements that reduce costs while benefiting wildlife. For example, many structures that are installed to facilitate the flow of water can be modified to better accommodate wildlife passage by incorporating a ledge. Additionally, rows of stumps and branches can be used in existing underpasses to enhance movement and connectivity for smaller animals.

Table 4.1 provides a rough cost comparison of different mitigation types for large passages. These estimates are based on engineering costs during the 1995-1997 Trans-Canada Highway upgrade project, Banff National Park, Alberta, Canada (Forman et al. 2003).

Table 4.1: Specifications and costs of mitigation large wildlife passages

Mitigation Type	Dimensions (w x h)	Materials Cost
Box Culvert: Concrete	10 x 8 ft	$575 / ft
Elliptical Culvert: Corrugated Metal	23 x 13 ft	$1,100 / ft
Bridge: Open Span	39 x 16 ft	$10,000 - $12,500 / ft
Overpass	170 ft wide	$6,890 / ft

5 Catalog of Structure Designs

5.1 Fencing Applications

Figure 5.1: Various fence applications in Europe (FHWA/US DOT, 2002)

Figure 5.2: Wide mesh chain fence for large mammals, with a fine mesh fence border for small mammals and amphibians (FHWA/US DOT, 2002)

Figure 5.3: Fine plastic mesh fence for small animals and amphibians (Puky, 2003)

Figure 5.4: Chain link fence for large animals overlaid with fine plastic mesh fencing for small animals and amphibians (Puky, 2003)

Figure 5.5: Concrete trench and drop inlet with one-way pipe for amphibian crossing (FHWA/US DOT, 2002)

Figure 5.6: Fence for small animals and amphibians with turned-back end to prevent animals from approaching the road (Puky, 2003)

Figure 5.7: Lipped walls for amphibians (Critter Crossings Website, 2002)

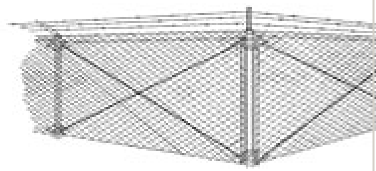
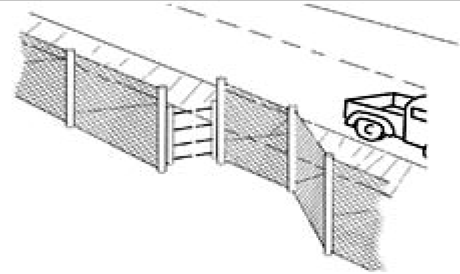
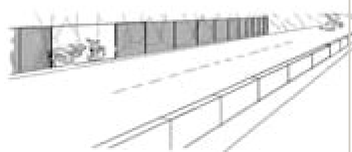
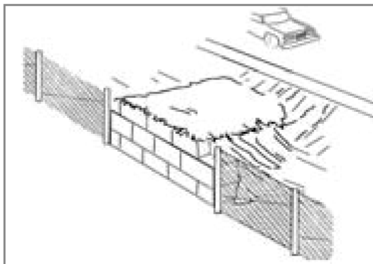
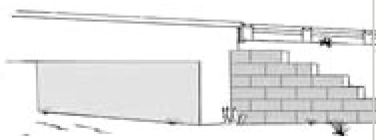
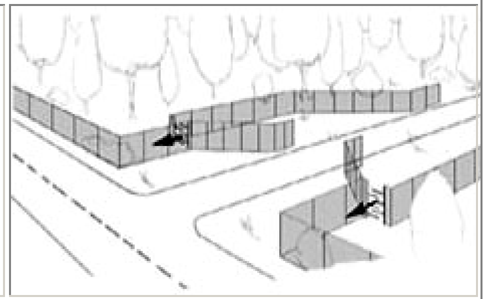
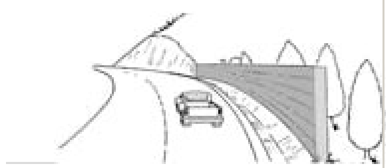
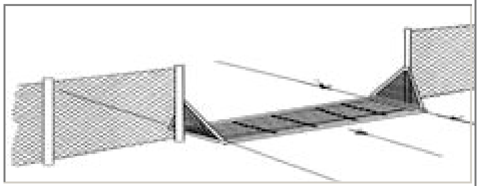
Fence		One-way Gate	
Jersey Barrier		Ramp	
Wall		Funnel Fence	
Sound Wall		In-roadway Barrier	

Figure 5.8: Various deterrence and escape mechanisms (Wildlife Crossing Toolkit)

5.2 Pipe Culverts

Figure 5.9: Small pipe culvert with mesh fence for small mammals and amphibians (FHWA/US DOT, 2002)

Figure 5.10: Arch culvert with fence for large mammals and lipped wall for amphibians (FHWA/US DOT, 2002)

Figure 5.11: Amphibian tunnel (Maibach, 2004)

Figure 5.12: Pipe culvert with fencing for medium mammals (NCHRP)

Figure 5.13: Various types of box culverts (Wildlife Crossing Toolkit)

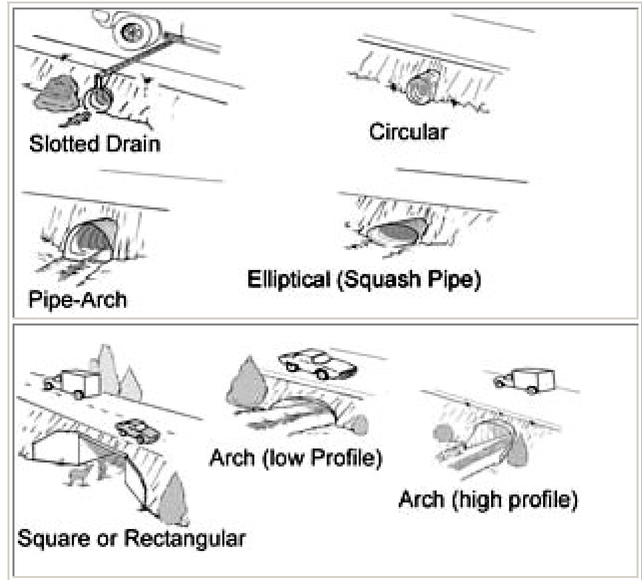


Figure 5.14: Small pipe culvert for small animals and amphibians (Critter Crossings, 2004)

5.3 Box Culverts

Figure 5.15: Fenced underpass for large wildlife (Defenders of Wildlife)

Figure 5.16: Box culvert underpass and fencing for multiple species (Puky, 2003)

Figure 5.17: Lipped wall and box culvert for amphibians (Puky, 2003)

Figure 5.18: Box culvert underpass with chain link fence for large animals (Cemagref, 2002)

Figure 5.19: Small box culvert for amphibians and small animals (Maibach, 2004)

Figure 5.20: Box culvert (National Cooperative Highway Research Program (NCHRP))

5.4 Ledges


Figure 5.21: Box culvert modified with ledge for wildlife passage (FHWA/US DOT, 2002)


Figure 5.22: Box culvert modified with ledge for small animal passage (Jackson, 2004)

5.5 Underpasses

Figure 5.23: Underpass to accommodate large and medium mammals, with stumps and vegetative cover for small animals (FHWA/US DOT, 2002)

Figure 5.24: Creek underpass in Banff National Park, Canada (Clevenger, 2004) http://www.pc.gc.ca/pn-np/ab/banff/docs/routes/chap1/sec1/routes1b_e.asp


Figure 5.25: Wildlife underpass in Banff National Park, Canada (Clevenger, 2004)


Figure 5.26: Wildlife underpasses (National Cooperative Highway Research Program (NCHRP))

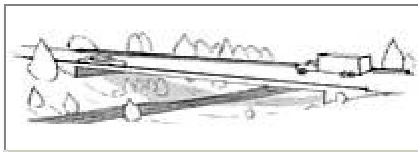
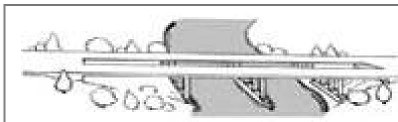
Structure Type	Description	Image
Single span bridge	The structure rests on abutments with no intermediate support columns. Also called *open span bridge*.	
Multiple span bridge	One or more intermediate support columns between abutments.	
Viaduct	Long, multiple-span bridge	
Causeway	Same as viaduct, only often over wetlands.	

Figure 5.27: Common underpasses (Wildlife Crossing Toolkit)

5.6 Overpasses

Figure 5.28: Overpass in Banff National Park, Canada (CPAWS, 2004)

Figure 5.29: Wildlife overpass (Deer-Vehicle Crash Information & Research Center)

Figure 5.30: Wildlife overpass to accommodate multiple species (FHWA/US DOT, 2002)

Figure 5.31: Wildlife overpass, or "green bridge" (NCHR)

Figure 5.32: Wildlife overpass (Jackson)

5.7 Wildlife Crossing Signs

Figure 6.33: Wildlife corridor informational sign from Riverside, CA

Figure 6.34: Frog crossing signs

Figure 6.35: Elk crossing sign (www.teresco.org/ pics/signs)

Figure 6.36: Bobcat crossing sign


Figure 6.37: Deer crossing sign with flashing lights (Friedman, 2005)

Figure 6.38: Seasonal crossing sign

Figure 6.39: Wildlife crossing sign for birds (Takahashi1999)

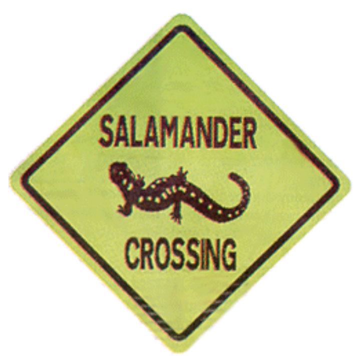


Figure 6.40: Salamander crossing

5.8 Problems to Avoid

Figure 5.41: Perched pipe.

Figure 5.42: Culvert with standing water.

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