



Guidelines for Improving Connectivity for Terrestrial and Aquatic Wildlife on the I-70 Mountain Corridor

I. CONSIDERATIONS FOR TERRESTRIAL PERMEABILITY

Medium and Large-Sized Box or Arch Culverts and Bridges

A) CREATE OR MAINTAIN FUNCTIONAL WILDLIFE CROSSINGS FOR MEDIUM-SIZED AND LARGE ANIMALS AT AN AVERAGE INTERVAL OF 1 MILE OR LESS ALONG THE I-70 MOUNTAIN CORRIDOR, DEPENDING ON ANIMAL MOVEMENT PATTERNS, TOPOGRAPHY AND HABITAT FEATURES TO PROVIDE PASSAGES FOR MEDIUM AND LARGE-SIZED ANIMALS. TO ACCOMPLISH THIS:

1. Where a drainage structure (culvert, concrete box culverts (CBC) or bridge) is needed as part of the highway system, install, modify or maintain existing drainage structures to accommodate wildlife movement

Where terrain permits and where it is practical:

- a) Install the largest bridge (preferably) or culvert practicable for any given location or terrain.
- b) Replace a bridge with a bridge of equal size or larger. Replace a culvert with a bridge, arch culvert, box culvert, or buried-bottom pipe of equal size or larger.¹
- c) Install the shortest structure practicable for a given roadway width, while maximizing structure width (span) to maximize openness and avoid a ‘tunnel effect’. Make structures wider rather than taller. Wide underpasses allow animals to have a broad viewing area, which makes them feel less vulnerable.
- d) Consider two shorter underpasses with a median or ‘atrium’ instead of one long structure under four or more traffic lanes.
- e) Ensure visibility from one end of a structure to the other.

¹ For species-specific design and dimensional specifications, use the following references:
Clevenger, A. P. and M. P. Huijser. 2011. Wildlife crossing structures handbook: design and evaluation in North America. Federal Highway Administration Report No. FHWA-CFL/TD-11-003. Lakewood, CO. [see Chapter 4]
Kintsch, J. and P. Cramer. 2011. Permeability of existing structures for wildlife: developing a passage assessment system. Washington Department of Transportation Report No. WA-RD 756.1. Olympia, WA. [see Tables 1 & 2]

- f) Maintain a natural substrate underneath the bridge. If concrete is necessary to prevent scour, then it is recommended to cover the concrete with a natural substrate. Install baffles to retain sediment and prevent scour.
- g) Use flooring of native material. For passages with perennial or ephemeral water flow, design structures to be wide enough to provide a dry pathway at least 3' wide for animals to use on one or both sides of the waterway.
- h) Engineer structures to minimize traffic noises for animals inside of or at the entrance to a structure (e.g., use noise-absorbing surfaces inside underpasses to reduce resonating noise, and/or use quiet pavement to reduce the extent of a road's noise disturbance zone).
- i) Limit roadway lighting where crossing structures are located.
- j) Use vegetated 'green screens' or other mechanisms along the sides of over-crossings to reduce highway noise and lights from animals on the structure.
- k) Solid bridge railings should be installed immediately above under crossings to reduce highway noise and lights for animals crossing below.
- l) Remove barriers at structure entrances that could prevent wildlife passage including, fencing or gates, boulders, rip-rap, or provide a pathway for wildlife through the obstruction.
- m) Maintain or restore native vegetation immediately adjacent to the structure at each entrance to encourage wildlife activity, provide natural cover and filter traffic light and noise. Use native vegetation seed to encourage wildlife use, promote establishment and suppress weedy species.
- n) Avoid using rip-rap or boulders to maintain aprons at the culvert entrances as these may be difficult for hooved animals to negotiate. If a rip-rap apron must be used, consider placing topsoil over the rip-rap along the edges so as to create a natural path or game trail.
- o) Design passage characteristics for both mobile species as well as limited-mobility species (e.g., pile up stumps or boulders along the inside wall of a large underpass to provide small mammal cover).

2. Locate additional structures at points where "Linear Wildlife Guideways" intersect I-70, where wildlife prefer to cross

Linear Wildlife Guideways are natural travelways defined as topographical ridges or drainages, sharply delineated changes in vegetation, or vegetation forming a peninsula. The intersection of a linear guideway with a roadway often creates a well-defined, intensely used crossing zone.

- a) Maintain vegetated ridges and drainages or other sharply defined changes in vegetation inside, and if possible outside the Right of Way.
- b) Use fencing to direct animals toward underpass crossings and away from road approaches.
- c) Reduce distance to cover by maintaining natural vegetation around the inflow and outflow of drainage structures, preferably in the form of vegetated peninsulas.
- d) Secure lands adjacent to crossing structures for long-term habitat protection.

3. Construct CBCs and bridges using natural colors and textures

- a) Construct sloped side supports instead of vertical walls. Use the lowest angle possible and natural substrate for abutment slopes.
- b) If support slopes are steep and/or rip-rap must be used for abutment slopes, construct a flat, dry pathway at least 5' wide cut into each slope.
- c) Use open support pillars instead of walls for structures with a long span.
- d) Avoid the use of mesh erosion control netting, which may ensnare snakes.

4. Design and maintain fencing to prevent wildlife from crossing at high-risk areas and to lead them to Wildlife Road Crossings

- a) Fencing for large mammals should be at least 8' high, with a mesh size less than 10cm x 15cm, without gaps between the fence and the ground and, where required to prevent animals from digging underneath, seated at least 15cm into the ground.²
- b) Avoid constructing fencing for > 1 mile without providing suitable safe crossing opportunities.
- c) Fencing should be placed the entire length between structures and in medians between culvert/bridge openings to prevent animals from entering the roadway from the median.
- d) Ensure that fencing is fully connected to structures without gaps.
- e) Minimize “natural ladders” adjacent to the fence which could facilitate an animal climbing over the fence (e.g. trees, large bushes, etc.).
- f) Construct and/or reposition wildlife fencing such that all culvert outlets (large and small culverts) are located outside of the ROW.
- g) Construct escape ramps at regular intervals to provide escape routes for animals trapped inside of the ROW.
- h) Use control mechanisms such as double cattle guards and electric mats to prevent animals from entering the ROW through gaps in the fencing (e.g., at interchanges).
- i) Curve fence ends back into the landscape away from the ROW and/or use boulder piles at fence ends to discourage wildlife from crossing the roadway at fence ends.
- j) Provide human access through fencing in areas where access is important to prevent people from damaging the fencing (e.g., ladders over the fencing, small angular passageways through the fence where a human could walk through but an animal could not, or, for private land access only, gates).

² For fencing specification, refer to:

California Department of Transportation Wildlife Crossing Guidance Manual (p. 61):

http://dap3.dot.ca.gov/hq/env/bio/wildlife_crossings/

Arizona Department of Transportation Wildlife Funnel Fencing Summary:

http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Funnel_Fencing/Wildlife_Funnel_Fencing_Summary.pdf

5. Where guard rails, retaining walls or jersey barriers or steep road cuts are required, keep in mind that barrier ends tend to funnel animals onto the roadway

- a) Locate the ends of barriers where there is a good line of sight to give motorists adequate time to avoid animals that enter the roadway at these locations.
- b) Consider locating wildlife crossings at the end of barriers where appropriate, based on wildlife movement patterns, topography and habitat features.

6. Avoid offsetting culverts and bridges where multiple structures are needed under a divided highway or where two roads run parallel to one another so that animals have a straight line of sight through all of the structures

7. Install features to minimize or prevent human use of wildlife crossing structures such as signs or barriers at potential access points

8. Install bird poles along wetlands or bridges to force birds to fly higher over the roadway

9. Add features to bridges to promote day and night roosting for bats, where appropriate

- a) To function as day roosts, bridges should be greater than 10' above the ground, have vertical crevices 0.5 to 1.25" wide, have vertical crevices 12 inches or greater in depth, be sealed from rainwater and debris entering from above, have full sun exposure, and not be situated over a busy roadway passing underneath the structure.
- b) To function as a night roost, bridges constructed from pre-stressed concrete girder spans, cast in place spans, or steel I-beams are best. Bats also prefer vertical concrete surfaces located between beams that provide protection from wind and remain warm at night.

10. Develop wildlife-friendly maintenance practices, such as lead paint recovery and timing of operations

11. Conduct monitoring of wildlife use of new and retrofitted structures (e.g., remotely-triggered cameras, track beds) to assess effectiveness of mitigation measures for the purpose of making appropriate adjustments as needed and improving designs of future mitigation measures

Small Box or Pipe Culverts

A) CREATE OR MAINTAIN FUNCTIONAL WILDLIFE CROSSINGS AT AN AVERAGE INTERVAL OF 1/4 MILE OR LESS ALONG THE I-70 MOUNTAIN CORRIDOR TO PROVIDE PASSAGES FOR SMALL MAMMALS. TO ACCOMPLISH THIS:

1. Where a drainage structure (culvert, concrete box culverts (CBC) or bridge) is needed as part of the highway system, install, modify or maintain existing drainage structures to accommodate wildlife movement.

Where terrain permits and where it is practical:

- a) Replace small drainage culverts with culverts of no less than 3' diameter for small-bodied animals or 4' for medium-bodied animals (e.g., coyotes and bobcats), unless terrain does not permit. When installing equalizer pipes between wetlands with small mammal ramps, pipes must be minimum 4' diameter.
- b) Install concrete pipes rather than corrugated steel, as the concrete provides a better surface for wildlife movement and absorbs some moisture, which can facilitate movement for some species.
- c) Consider installing a low-gradient dry culvert for wildlife passage adjacent to a steep gradient drainage culvert.
- d) Culverts should be built or modified with dry ledges for use by water-shy organisms; these ledges should be constructed to be able to withstand flood events.
- e) Routine maintenance of culverts is essential to maintain culvert functionality for wildlife movement to remove accumulated sediment or other obstructions inside the culvert or at the culvert entrances.
- f) Maintain natural vegetation cover, including low-stature cover for amphibians.
- g) Avoid using rip-rap or boulders to maintain aprons at the culvert entrances as these may be difficult for some small animals to negotiate. If a rip-rap apron must be used, consider placing topsoil over the rip-rap along the edges so as to create a natural path or game trail.
- h) Integrate fencing and structures to guide animals to crossing structures. Fencing at small culverts used by medium-bodied animals (e.g., coyotes and bobcats) should be 3-6' high, while fencing for small-bodied animals should be at least 3' high with a small mesh size and entrenched into the ground several inches to prevent animals from digging under. For reptiles and amphibians, a fine mesh fence, concrete walls, or aluminum flashing may be used. Remove and maintain trees, brush, etc that could allow an animal to climb over the fence.
- i) Construct and/or reposition wildlife fencing such that all culvert outlets are located outside of the ROW.

2. Enhance existing and new structures with the installation of small mammal ramps or rock walkways that extend the length of a culvert so that small mammals can cross even in wet conditions. Small mammal ramps in culverts are particularly recommended where the roadway bisects a wetland or riparian zone³

3. Where possible, use cable median and shoulder barriers instead of jersey-style walls. Where concrete median or shoulder barriers are required, install jersey barriers with ‘scuppers’ or small openings on the bottom, or barriers with intermittent gaps to allow small mammals to pass through (note: the effectiveness of such gaps has not yet been proven or disproven).

³ For small mammal ramp guidelines, refer to:
Montana Department of Transportation Small Mammal Ramp Guidelines.

II. CONSIDERATIONS FOR FISH PASSAGE

A) MAINTAIN OR RESTORE STRUCTURAL AND FUNCTIONAL CONNECTIVITY FOR FISH SPECIES (BOTH ADULTS AND JUVENILES) AT ALL ROAD-STREAM CROSSINGS. TO ACCOMPLISH THIS:

1. Design new structures at road-stream crossings to facilitate fish passage

Where practical:

- a) Retain, restore or mimic the existing physical and morphological conditions in the stream and floodplain to the greatest extent possible. Use stream simulation techniques and appropriate reference reaches to guide the design and construction of new or replacement structures, with the aim of creating conditions inside the structure as similar as possible to the stream channel in both structure and function (refer to: http://stream.fs.fed.us/fishxing/aop_pdfs.html)
- b) Replace a culvert with an oversized arch culvert, 3-sided box culvert, open-bottomed pipe culvert, or entrenched pipe culvert that is wide enough to prevent channel constriction by accommodating the full channel width and allow for design flows (i.e., natural substrate through culvert, bottom surface of structure should be flush with grade, no drop-offs or plunge pools, and minimize turbulence and channel constriction).
- c) A bridge overpass alignment should encompass the natural floodplain, including meanders and riparian banks, and allow for minimal use of bank armoring strategies such as riprap or concrete wall bridge supports.
- d) Minimize culvert length to the greatest extent possible within the natural course of the stream. Where a stream crosses an extended highway footprint and associated infrastructure (e.g., highway on/off ramps, frontage roads, adjacent developed areas), install multiple shorter culverts rather than one long culvert.
- e) Minimize the degree of forced changes in flow direction, by installing a wider structure that accommodates a natural stream meander as it passes under the road or by installing a curved culvert to better preserve inlet and outlet channel alignments and to prevent bank scour, undercutting or structural failure.
- f) Design culverts such that water velocity, depth and grade through the structure is consistent with upstream and downstream channel conditions.
- g) Design passages with consideration of the impacts of both high and low flows on fish passage. Design velocity criteria to provide passage for the weakest swimming individual (e.g., juveniles) during a range of flow conditions.
- h) Provide low-flow channels in culverts where needed by installing the invert of the culvert below the grade of the natural substrate of the stream to ensure that a minimum water depth can be preserved through the culvert as flow levels fluctuate (e.g., in streams where flow depth may seasonally drop below the minimum depth required for fish passage).

- i) Decrease maximum flow velocity through a culvert as culvert length increases and provide rest areas for fish moving through the culvert.
- j) Daylight long culverts as much as practically possible while providing best management practices and natural riparian vegetation for controlling for the inflow sediment and runoff from the roadway.
- k) Plant and maintain native riparian vegetation at the inlets and outlets of all crossings.
- l) Maintain road sand traps to prevent the siltation and pollution of streams and provide regular maintenance to prevent sediment build-up or debris accumulation at culverts.
- m) Construct wetlands along the highway right-of-way wherever practical to reduce nonpoint source pollution into receiving streams and funnel roadway sediment and runoff to sediment traps or vegetated buffer areas away from stream channels.
- n) Install flared end sections on culverts to reduce erosion at the inlets and outlets of water conveyance structures.

2. Retrofit existing culverts that are not due for immediate replacement to facilitate fish passage.

- a) Install securely anchored baffles (corner or side) or rock weirs and provide streambed substrate inside the culvert to add roughness, reduce flow velocity, increase flow depth through the culvert, and create pools that can act as resting areas for fish moving through the culvert where flow criteria allows for reduced culvert capacity. Design baffle heights and profiles with consideration for high and low flows.
- b) Install weirs to concentrate low flows into multiple pools with narrower, deeper channels where needed to ensure that a minimum water depth can be preserved through the culvert as flow levels fluctuate (e.g., in streams where flow depth may seasonally drop below the minimum depth required for fish passage). Use tailwater control weirs outside of the culvert barrel to increase flow depths in the culvert during periods of low flow.
- c) Use rocks in culverts to simulate the grade-stabilizing functions of embedded debris.
- d) Improve transitions at culvert inlets and outlets to accommodate for forced changes in flow direction due to skewed culverts.
- e) Balance control measures by installing flared end sections or control weirs for slowing flow velocities and excessive turbulence at culvert inlets
- f) Repair perched outfalls by constructing step/pool structures with natural materials to allow for aquatic connectivity. Provide a sufficient pool depth at outlets where fish have to jump to enter a culvert. Design jump height for specific species of concern.
- g) Maintain culvert improvements to prevent them from becoming clogged with sediment or debris.
- h) Plant and maintain native riparian vegetation at the inlets and outlets of all crossings.

3. Integrate aquatic and terrestrial connectivity goals at all road-stream crossings as appropriate (e.g., include dry pathways for terrestrial species, as needed)

- a) Oversize crossing structures to accommodate both aquatic and terrestrial species.
- b) Install multiple crossings at varying invert elevations that can perform as dry crossings for terrestrial species and low flow crossings for aquatic species while improving the morphological characteristics of the floodplain and allowing for increased flow capacity during high runoff events. Note that multiple structures at one site may have higher maintenance demands than a single larger structure, and the main crossing structure must be large enough to accommodate flows, sediment and debris.

4. Coordinate with the Colorado Division of Wildlife

- a) Aquatic connectivity is not always desirable. Install or maintain aquatic barriers where needed to control the spread of invasive species or disease and/or to protect pure populations of native species. Likewise, remove barriers that no longer serve their intended purpose.
- b) Obtain information on the types of species occupying specific streams and design the range of flow velocities, water depth and other attributes for those specific species and life stages. Where such information is lacking, unless there is an explicit need for an aquatic barrier, design road-stream crossings to facilitate fish and aquatic organism passage.
- c) To determine the most cost-effective use of funds for constructing new structures or retrofitting existing structures, consider the road-stream crossing relative to the entire stream network, including how it relates to other road-stream crossings or barriers.

5. Minimize impacts to aquatic species during construction

- a) Concentrate construction activities during periods of low flow to avoid critical time periods such as fish migration and spawning seasons, and to minimize direct impacts to wildlife and their habitat.
- b) Minimize disturbance to the length of the natural stream channel and natural flow of water as well as to the riparian banks and vegetation, and restore areas that have been disturbed using local materials and seed.
- c) Clean all equipment and gear before and after they are exposed to the stream to prevent the transmission of aquatic nuisance species or aquatic diseases into or out of the drainage.
- d) Remove temporary fills and structures once construction is complete.
- e) Install and maintain all best management structures to reduce sedimentation into a stream during construction and remove all temporary BMP's once natural vegetation has been re-established.