Title:
Use of video surveillance to assess wildlife behavior and use of wildlife underpasses in Arizona

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Abstract:
We used integrated, four-camera video surveillance systems to assess and compare wildlife use of five openspan bridged wildlife underpasses along a 30-km stretch of reconstructed highway in central Arizona. We determined passage rates (proportion of animals approaching and crossing through underpasses) and categorized behavioral responses exhibited during underpass approaches and crossings. Two underpasses have been monitored for over 2-1/2 years; both open into the same meadow/riparian complex, are only 225 m apart, but have different below-span characteristics and dimensions, providing an excellent opportunity to compare use by wildlife. Four underpasses, in place for 18 months, have been monitored for over one year; two of these allowed for monitoring before ungulate-proof fencing was erected in association with the underpasses. This allowed us to record pre- and post-fencing passage rates and behavior to assess the role of fencing in funneling animals to underpasses and influencing passage rates. At the two adjacent underpasses monitored over 2-1/2 years (December 2002-June 2005), we recorded eight species of wildlife totaling 3,914 animals, including 3,548 elk (Cervus elaphus nelsoni), 216 white-tailed deer (Odocoileus virginianus cousei), and 6 species of carnivores including 4 mountain lions (Puma concolor). Overall, elk passage rates averaged 0.62, while only 15 deer

crossed the underpasses (0.075 passage rate). We detected significant differences in passage rate and behaviors indicative of resistance to crossing. One underpass with earthen 2:1 sloped sides has been used more by elk (1,908 elk) displaying less resistant behaviors and delay in crossing compared to one with concrete walls (598 elk). This information was used in an adaptive management context to minimize concrete walls and pursue alternatives to soil stabilization at a wildlife underpass currently under construction. At the three recently completed underpasses, monitored February 2004-June 2005, we recorded 10 species of wildlife totaling 1,703 animals, including 860 elk, 367 white-tailed deer, 194 mule deer (O. hemionus), and 7 species of carnivores. Elk passage rates to date averaged 0.35, with the passage rate at two underpasses exceeding 0.50 and two below 0.27. Both white-tailed and mule deer regularly used the newer underpasses with passage rates of 0.40 and 0.29, respectively. Ungulate-proof fencing was completed through the underpasses in December 2004, and we continue to monitor wildlife response and changes in passage rates since this fencing was erected. Video surveillance constitutes a valuable tool in quantifying wildlife use of underpasses and assessing the effectiveness of underpasses and fencing. Continued monitoring will allow us to assess long-term use of passage structure.

USE OF VIDEO SURVEILLANCE TO ASSESS WILDLIFE BEHAVIOR AND USE OF WILDLIFE UNDERPASSES IN ARIZONA

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Abstract: We used integrated, four-camera video surveillance systems to assess and compare wildlife use of five open-span bridged wildlife underpasses along a 30-km stretch of reconstructed highway in central Arizona. We determined passage rates (proportion of animals approaching and crossing through underpasses) and categorized behavioral responses exhibited during underpass approaches and crossings. Two underpasses have been monitored for over 2-1/2 years; both open into the same meadow/riparian complex, are only 225 m apart, but have different below-span characteristics and dimensions, providing an excellent opportunity to compare use by wildlife. Four underpasses, in place for 18 months, have been monitored for over one year; two of these allowed for monitoring before ungulate-proof fencing was erected in association with the underpasses. This allowed us to record pre- and post-fencing passage rates and behavior to assess the role of fencing in funneling animals to underpasses and influencing passage rates. At the two adjacent underpasses monitored over 2-1/2 years (December 2002-June 2005), we recorded eight species of wildlife totaling 3,914 animals, including 3,548 elk (*Cervus elaphus nelsoni*), 216 white-tailed deer (*Odocoileus virginianus cousei*), and 6 species of carnivores including 4 mountain lions (*Puma concolor*). Overall, elk passage rates averaged 0.62, while only 15 deer crossed the underpasses (0.075 passage rate). We detected significant differences in passage rate and behaviors indicative of resistance to crossing. One underpass with earthen 2:1 sloped sides has been used more by elk (1,908 elk) displaying less resistant behaviors and delay in crossing compared to one with concrete walls (598 elk). This information was used in an adaptive management context to minimize concrete walls and pursue alternatives to soil stabilization at a wildlife underpass currently under construction. At the three recently completed underpasses, monitored February 2004-June 2005, we recorded 10 species of wildlife totaling 1,703 animals, including 860 elk, 367 white-tailed deer, 194 mule deer (*O. hemionus*), and 7 species of carnivores. Elk passage rates to date averaged 0.35, with the passage rate at two underpasses exceeding 0.50 and two below 0.27. Both white-tailed and mule deer regularly used the newer underpasses with passage rates of 0.40 and 0.29, respectively. Ungulate-proof fencing was completed through the underpasses in December 2004, and we continue to monitor wildlife response and changes in passage rates since this fencing was erected. Video surveillance constitutes a valuable tool in quantifying wildlife use of underpasses and assessing the effectiveness of underpasses and fencing. Continued monitoring will allow us to assess long-term use of passage structure.

Introduction

With the ever-increasing importance of finding ways to get wildlife safely across a highway it is necessary to share information obtained from current studies to assist in future wildlife-vehicle collision mitigation efforts. In this paper we share measurements, descriptions, and photos of wildlife underpasses and preliminary data obtained during monitoring to allow researchers to draw their own conclusions as well.

The main objectives of this paper are to (1) discuss the use of video surveillance to monitor wildlife underpasses, (2) describe the five wildlife underpasses monitored and provide data and photos for each, (3) provide data obtained from pre- and post-fencing monitoring at wildlife underpasses, and (4) discuss possible design and placement criteria that may affect wildlife underpass use.

Methods for Monitoring Wildlife Underpasses

Wildlife video surveillance system components and camera orientation

We used integrated, four-camera wildlife video surveillance systems to monitor each of the six underpasses. Two cameras were oriented in a manner to document approaches by wildlife within approximately 50 m of the underpass, one camera was placed in the underpass to assess usage and behavior within the underpass, and one camera was oriented toward the highway to assess traffic (fig. 1). A quad screen splitter allowed for simultaneous viewing of all four cameras (fig. 1). Eight to twelve infrared illuminators were incorporated to allow night-time viewing of wildlife. Infrared photo-beam triggers encompassed the area around the underpass to allow video recording only when wildlife was in the area. Systems comprised both solar and 120-volt A.C. power sources converted to 12-volt to operate equipment.

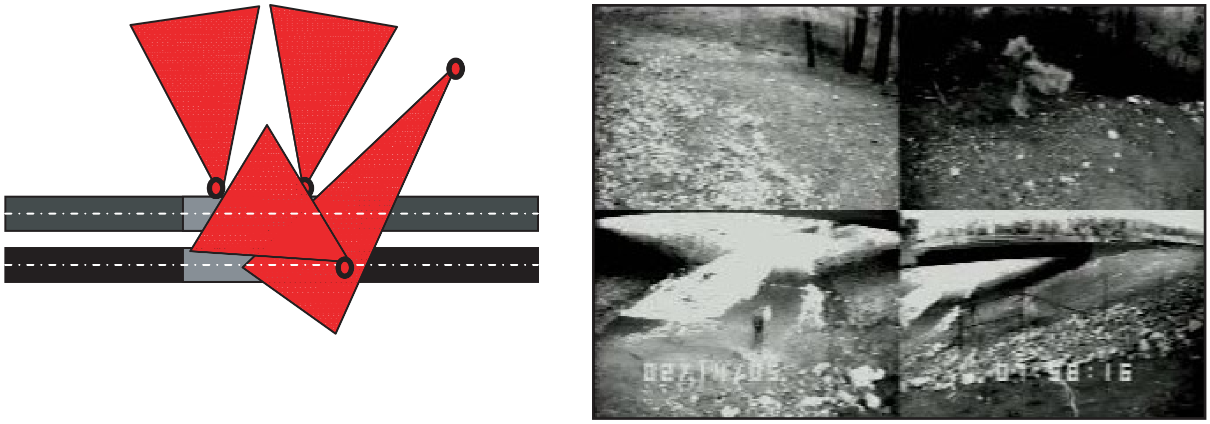


Figure 1. Typical camera orientation and quad screen view of 4-camera wildlife video surveillance systems.

Data collected from wildlife underpass video analysis

The following information was collected for each wildlife observation (UP=underpass):

Date	Tape Time	Time Start
Time End	Total Time	Camera Off Time
Species	Sex	# approach UP
# Use UP	Dir. of Travel	Time approach to cross
Delay level during cross (3)	# did not cross	# enter UP and retreat
# exhibit flight	# standing/milling	# feeding
# did not approach	# vehicles total	# in UP with veh. overhead
Reaction to veh. (4)	Type of veh. (semi / car)	Pre-fencing behavior (4)

Calculation of passage rates

Passage rate is determined by the following equation: # use underpass/# approach underpass. Approaches are classified when animals come within approximately 50 m of the mouth of the underpass and show movement toward the underpass. Passage rate is only calculated from the side of the underpass the cameras are oriented. Any wildlife using the underpass from the other side are documented but not incorporated into the passage rate.

Dimensions and Descriptions of Wildlife Underpasses Monitored by Video Surveillance

Preacher Canyon section

The Preacher Canyon section consists of two wildlife underpasses and one large bridge along an 8-km section of highway. We focused our monitoring efforts on the two wildlife underpasses that are located within only 225 m of each other, allowing wildlife access to the same riparian meadow (Little Green Valley) and providing a unique opportunity to compare usage and behaviors associated with the underpasses. These two underpasses have been complete since 2001, and we have monitored them with video surveillance for approximately 2-1/2 years.

West Little Green Valley Underpass

Year completed:	2001
Dimensions:	-Span distance - 37.7 m -Maximum height - 11.5 m -Width at floor - 16.0 m -Total length (approach to approach) - 110.6 m
Features:	-Divided highway (11.0-m atrium between bridges) -Mechanically stabilized earth (MSE) walls to 6.4 m height -Limited (400-m) wildlife-proof fencing along highway linking the underpass to the East Little Green Valley Underpass
Total Usage:	**623 animals** Passage Rate: **53.5%** Total Monitoring: **31 months**

Figure 2. West Little Green Valley Underpass.

East Little Green Valley Underpass

Year Completed:	2001
Dimensions:	-Span distance - 37.7 m -Maximum height - 6.8 m -Width at floor - 9.6 m -Total length (approach to approach) - 52.7 m
Features:	-Divided highway (11.0-m atrium between bridges) -2:1 sloped earthen sides -Limited (400-m) wildlife-proof fencing along highway linking the underpass to the West Little Green Valley Underpass (fencing tied into abutments)
Total Usage:	**1,955 animals** Passage Rate: **70.1%** Total Monitoring: **31 months**

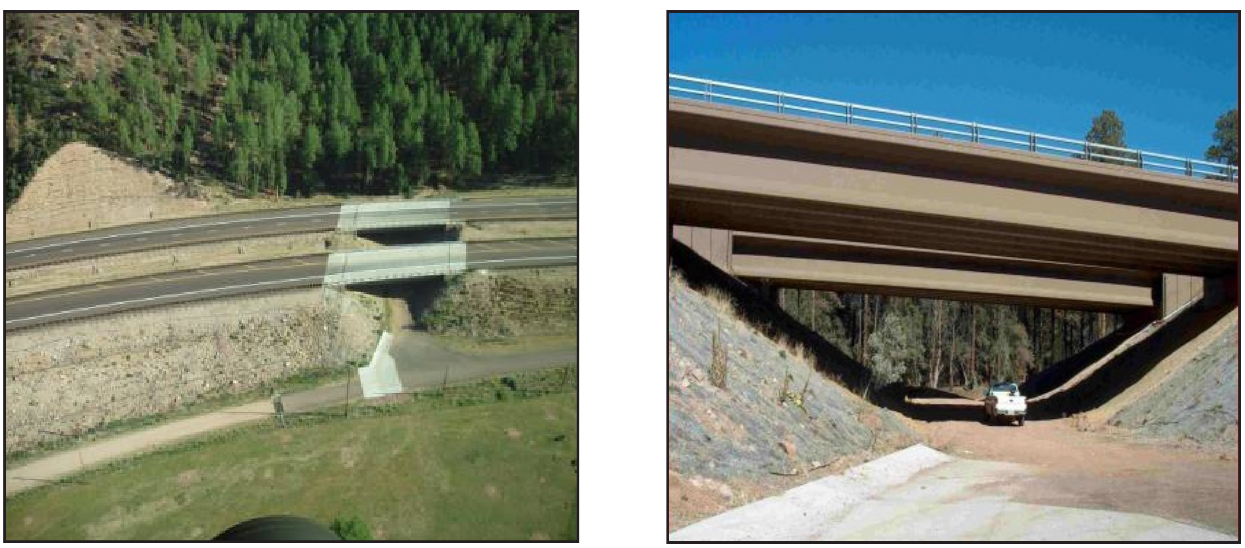


Figure 3. East Little Green Valley Underpass.

Christopher Creek section

This is the second phase of the highway upgrade and is approximately 8 km in length. This section incorporates four wildlife underpasses and three large bridges to accommodate wildlife passage. This section was completed in 2004, and we have monitored three of the crossing structures with video surveillance for 15 months and will continue to monitor for a minimum of two more years.

Pedestrian -Wildlife Underpass

Year Completed:	2004
Dimensions:	-Span distance – 34.2 m (east-bound) 31.9 m (west-bound) -Maximum height – 6.8 m -Width at floor – 7-9 m -Total length (approach to approach) - 128 m
Features:	-Divided highway (47.9-m atrium between bridges) -This underpass also serves as a pedestrian underpass linking 2 communities (Christopher Creek and Hunter Creek) -Wildlife-proof fencing extends >2 km to the east, funneling animals to the underpass; to the west, large, steep fill slopes and right-of-way fencing at the top of the slope behind a guard rail should also serve to funnel animals to the underpass.
Total Usage:	**407 animals** Passage Rate: **63.3%** Total Monitoring: **15 months**

Figure 4. Pedestrian-Wildlife Underpass.

Wildlife Underpass #2

Year Completed:	2004
Dimensions:	-Span distance – 39.9 m -Maximum height – 10.0 m -Width at floor – 8-10 m -Total length (approach to approach) - 118.8 m
Features:	-Divided highway (31.9-m atrium between bridges), with the bridges offset (fill material was removed to improve the sight distance through the atrium) -2:1 sloped earthen sides -Wildlife-proof fencing extends >2 km in each direction, funneling wildlife toward the underpass. Fencing through the underpass was completed mid-October 2004 (15 m wide)
Total Usage:	**281 animals** Passage Rate: **31.6%** Total Monitoring: **15 months**

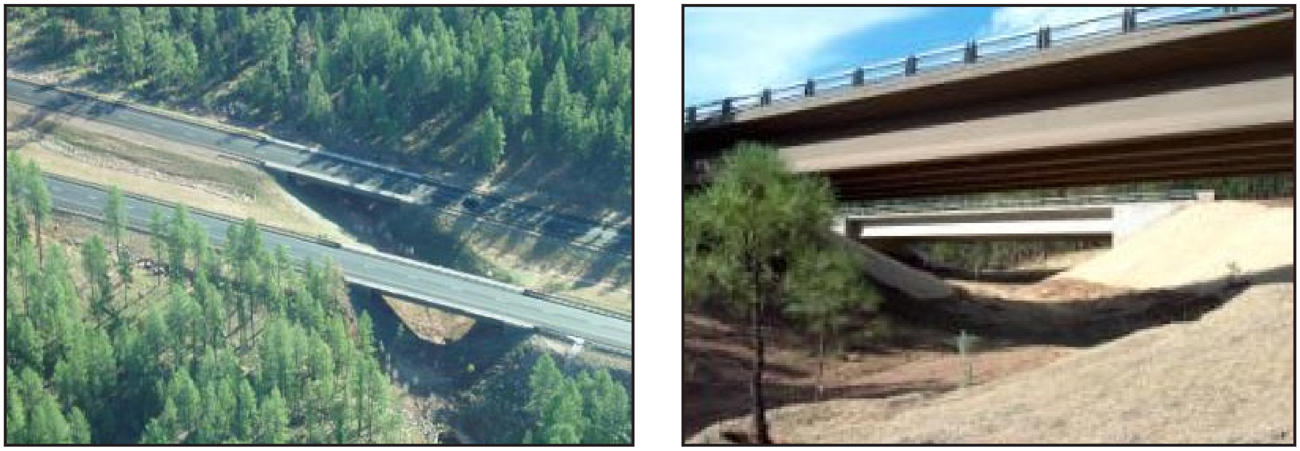


Figure 5. Wildlife Underpass #2.

Wildlife Underpass #3

Year Completed: Late 2003

Dimensions:
-Span distance – 37.7 m
-Maximum height – 5.1 m
-Width at floor – 10 m
-Total length (approach to approach) – 63.9 m

Features:
-Undivided highway (no atrium),
-2:1 sloped earthen (rip-rap rock) sides
-Wildlife-proof fencing extends 0.5 km in each direction, funneling wildlife toward the underpass. Fencing ties into the bridge abutments.
-This underpass is located in close proximity (<0.25 km) to an ADOT maintenance yard and residence (directly in line with the north underpass approach), potentially limiting wildlife use

Total Usage: **111 animals** Passage Rate: **37.7%** Total Monitoring: **15 months**

Figure 6. Wildlife Underpass #3.

Preliminary results of wildlife usage at the 5 wildlife underpasses
Table 1. All animals documented near each underpass, number using each underpass, and passage rates associated with each underpass

	Underpass	Period	Elk	Whitetail	Mule Deer	Black Bear	Mtn Lion	Coyote	Grey Fox	Raccoon	Other	Total
Wildlife on Video	West	(2.5 yrs)	1023	72	9	0	0	12	7	1	19	1143
	East	(2.5 yrs)	2525	143	2	2	4	58	26	5	6	2771
	Ped-Wildlife	(1.2 yrs)	296	281	30	2	1	5	18	133	3	769
	Wildlife 2	(1.2 yrs)	455	57	154	0	0	6	13	3	0	688
	Wildlife 3	(1.2 yrs)	51	29	4	0	0	0	1	89	1	175
	Total		4350	582	199	4	5	81	65	231	29	5546
□□sing Crossing	West	(2.5 yrs)	598	5	0	3	5	0	0	1	11	623
	East	(2.5 yrs)	1908	10	0	12	14	1	0	4	6	1955
	Ped-Wildlife	(1.2 yrs)	175	166	11	1	0	4	7	42	1	407
	Wildlife 2	(1.2 yrs)	127	32	110	0	0	4	6	2	0	281
	Wildlife 3	(1.2 yrs)	9	11	2	0	0	0	1	88	0	111
	Total		2817	224	123	16	19	9	14	137	18	3377
Passage Rate (%)*	West	(2.5 yrs)	56.8	11.6	0.0	NA	NA	50.0	61.6	100.0	66.6	53.5
	East	(2.5 yrs)	74.2	3.4	0.0	100.0	50.0	22.7	63.6	100.0	80.0	70.1
	Ped-Wildlife	(1.2 yrs)	57.0	60.0	14.3	0.0	0.0	50.0	50.0	60.4	33.0	63.3
	Wildlife 2	(1.2 yrs)	16.2	38.5	40.5	NA	NA	60.0	38.5	0.0	NA	31.6
	Wildlife 3	(1.2 yrs)	10.6	21.7	33.3	NA	NA	NA	NA	90.6	NA	37.7
	Total		45.3	27.0	17.6	50.0	25.0	45.7	42.7	75.2	44.9	52.0

* Passage rate calculated by cross/approach from camera side of underpass only

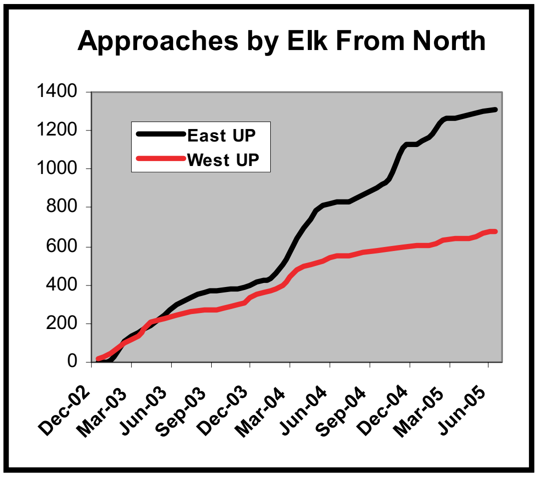
Comparison of Usage and Behaviors by elk at 2 Adjacent Wildlife Underpasses

We assessed and compared usage and behaviors at the east and west underpasses at Little Green Valley (see descriptions above) for a period of >2-1/2 years. The east and west underpasses are located within 225 m of each other. They allow wildlife access to the same riparian meadow and a unique opportunity to compare two different types of structures (fig. 7). The east underpass has natural 2:1 earthen slopes (fig. 3), while the west underpass incorporates walls (fig. 2). For this analysis, we focused on elk since their numbers were high, and the elk were large enough to allow us to readily see behaviors. During the 31 months we documented 3,543 elk in the vicinity of the two underpasses.

Figure 7. Aerial photo of the adjacent West (left) and East Little Green Valley underpasses on the Preacher Canyon section. These 2 underpasses are only 225 m apart, allowing for a unique opportunity to compare underpass designs.

Crossings and passage rates

Crossings at the east Little Green Valley underpass were greater than 3 times that of crossings at the west underpass. At the east underpass 1908 elk crossed through versus 598 through the west. This difference in usage holds true whether elk are entering or leaving Little Green Valley. Comparisons of the 2 underpasses over time show that the number of animals that approached each underpass from the camera side was roughly equivalent for the first 6 months, then begins to favor the East Underpass, while crossings were always higher at the east underpass (fig. 8).



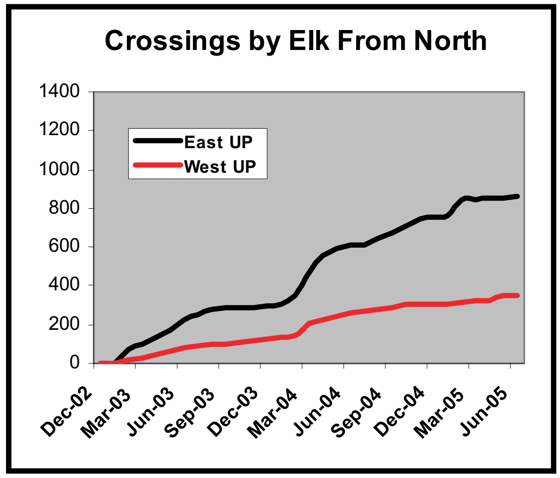


Figure 8. Approaches and crossings from camera side of east and west underpasses at Little Green Valley.

Behavioral comparison of the two underpasses at Little Green Valley

Of the individual elk that approached from the camera side of the underpasses, we identified four negative behaviors: (1) would not cross, (2) obvious delay in crossing, (3) enter underpass and retreat, and (4) alarmed flight from area. The percentage of elk that showed these negative behaviors were all higher at the west underpass (fig. 9).

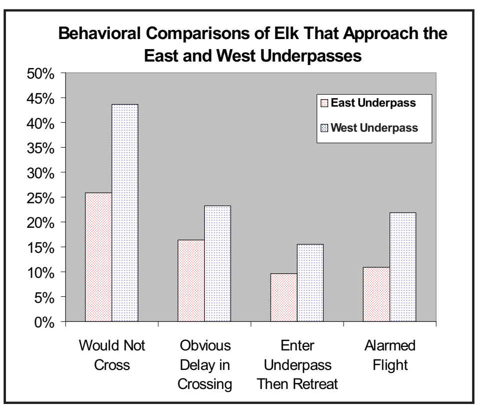


Figure 9. Comparison of 4 negative behaviors associated with elk approaching each underpass and an example of elk showing hesitation immediately prior to fleeing from the area, and exhibiting an unsuccessful crossing.

Possible reasons for differences in usage and passage rates

Below is a list of a few possible reasons for the differences that occur in usage and behaviors between the East and West underpasses at Little Green Valley.

1. Natural slopes versus MSE walls – The walls may provide an unnatural feel for wildlife using them.
2. Sound / Echoes created by walls – Sound was tested at the A-weighted scale, no significant difference in decibel levels.
3. Tunnel effect / Openness ratio – The west underpass is twice the length of the east, reducing the openness.
4. Ledges for predators to hide on walls – Some animals may fear the possibility of predators hiding on the ledges of the walls (fig. 10).
5. Differences in lighting of the 2 underpasses.

Figure 10. A common sight at the west underpass of elk looking up at the top of the walls, possibly for predators.

Adaptive management process at work
Arizona Game and Fish Department (AZGFD) met with Arizona Department of Transportation (ADOT) and Tonto National Forest to share the data obtained from the comparison of the east and west underpasses at Little Green Valley (fig. 7). The data were used to make recommendations for changes to the Indian Gardens wildlife underpass that was in the final planning stages. The underpass, now currently under construction, has significantly less MSE wall and has been widened to minimize tunnel effect and to potentially increase wildlife usage. AZGFD will begin video monitoring of the Indian Gardens wildlife underpass in fall of 2005.

Monitoring Ungulate-Proof Fencing Associated With Wildlife Underpasses

We monitored two wildlife underpasses for eight months prior to and six months following the completion of ungulate-proof funnel fencing. The two underpasses were constructed on a four-lane divided highway with a wide median (figs. 4 and 5).

Pre-fencing
Prior to completion of ungulate-proof fencing, we monitored the movements of 701 elk and deer in proximity to the two sets of underpasses for eight months. Of the 496 animals that approached from the camera side, 42 percent crossed over the highway versus using the crossing structure. Of the remaining elk that went through the first underpass 63 percent of those left via the median still crossing one set of lanes. Overall, only 20 percent of the elk and deer that crossed the highway corridor successfully crossed using both underpasses.

Post-fencing
Once installation was completed at the two underpasses, elk and deer could no longer cross over the highway in the area of the wildlife underpass, nor enter or leave via the median. Passage rates of elk and deer increased from 20 to 57 percent following installation of fencing. Mean daily usage by elk and deer more than doubled following installation of fencing (fig. 11).

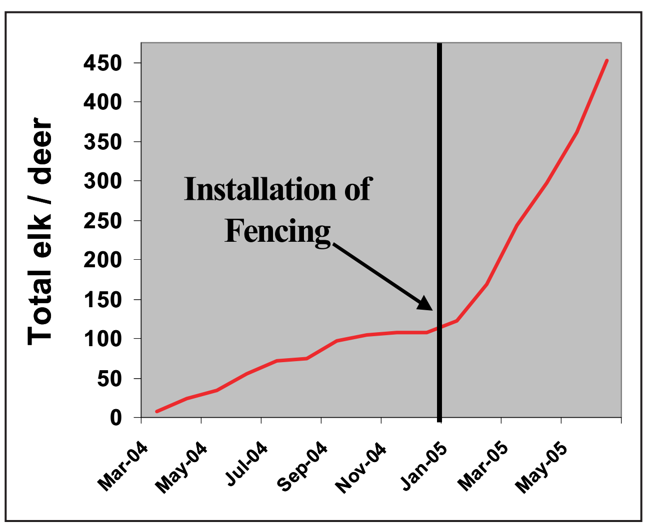
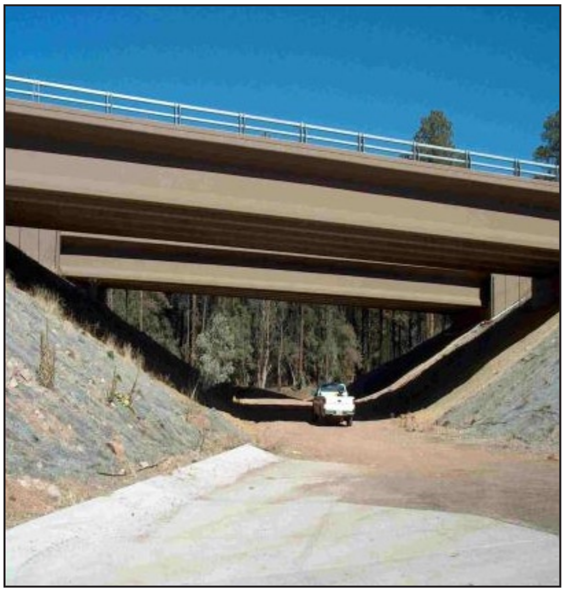
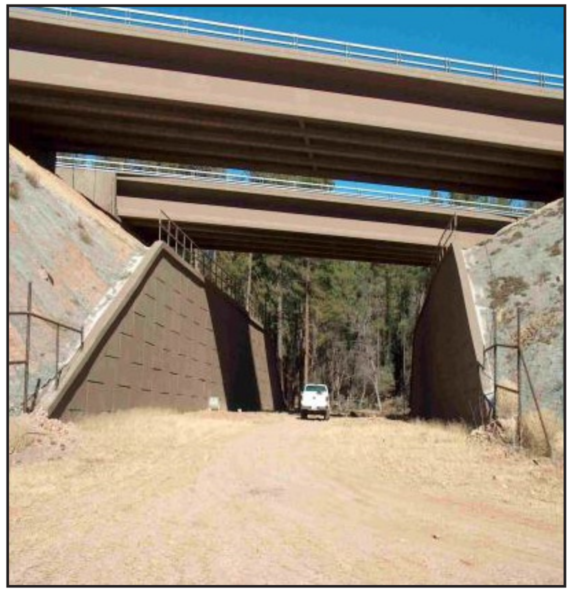


Figure 11. Cumulative usage by elk and deer of 2 wildlife underpasses during pre- and post- ungulate-proof fencing.

Underpass design and placement affecting wildlife underpass usage

Placement and designs of underpasses can be important in the success of a wildlife underpass. Below are some examples describing possible reasons why differences in usage or passage rates may exist at the underpasses along State Route 260.





Example 1: Above are the 2 underpasses located within 225 m of each other and feeding into the same riparian meadow (see figs. 2 and 3 for details). The one on the left has had >3X the number of elk and a relatively higher passage rate. Why? Tunnel effect / openness ratio? Unnatural feel of concrete walls? Ledges for predators to hide?

Example 2: Above is an underpass (see fig. 6 for details) that has shown very little use and very low passage rates (except for raccoon (*Procyon lotor*), this is probably due to the placement of the structure being so close to human activity. This underpass also lacks an atrium, forcing animals to cross under four lanes at once.

Example 3: Above are 2 underpasses that have had about the same number of deer approaches (see figs. 3 and 4 for details). The underpass on the left has only a 3% passage rate for deer, while the one on the right is at 59%. Some possible reasons for this may be the lack of cover on one side of the underpass on the left, or the large atrium created by the wide median at the underpass on the right, allowing deer to “take a break” before crossing under the second set of lanes.

Example 4: Above are 2 underpasses within about 2 km of each other (see figs. 4 and 5 for details). The underpass on the left has a passage rate for elk at about 27%, while the one on the right is about 59%. One possibility may be the offset of the underpass on the left minimizing the point where an elk can see all the way through the underpass. The width of the medians is approximately the same size (photos are taken at different heights). Long-term monitoring here may be important to determine if passage rate increases over time as elk learn these structures.

Conclusion

This portion of the Arizona State Route 260 project illustrates the value of using video surveillance as a method of assessing wildlife underpass use. Many behaviors that are documented by this method would not be readily seen with other methods. Data gathered from video surveillance allow us to make changes on future underpass designs and placements.

Fencing associated with wildlife underpasses is necessary to maximize effectiveness of the underpasses. Elk and deer preferred to cross the highway rather than use both sets of lanes without fencing. In our case passage rates for elk and deer increased approximately 40 percent, and continue to increase as wildlife learn underpass locations. Long-term monitoring is important to see changes in usage over time.

Design and placement, as well as knowledge of local species, can be very important in the ultimate success of a wildlife crossing structure. Different species may react differently to features such as cover on either side of an underpass, ledges, lack of visual openings through the underpass, tunnel effect or openness ratios, human activity, etc. Long-term monitoring can help determine if animals adapt to whatever design or placement is used.

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Biographical Sketches: Jeff Gagnon is a wildlife specialist for the Research Branch of Arizona Game and Fish Department. Mr. Gagnon's current research is focused on the Arizona State Route 260 Wildlife-Highways Interaction Project. He obtained his B.S. in biology–fish and wildlife management in 1998 from Northern Arizona University and is currently working on an M.S. in biology focusing on relationships of traffic levels to elk movements and distributions.

Norris Dodd has worked for the Arizona Game and Fish Department for 26 years, the past 11 as a wildlife research biologist. Since 2001, he has been working on wildlife-highway relationships research and management, focusing on the State Route 260 project in central Arizona. Mr. Dodd received his bachelor and master's degrees from Arizona State University. He is a past president of the Arizona Chapter of The Wildlife Society.

Amanda Manzo is a research intern for the Arizona Game and Fish Department on the Arizona State Route 260 Wildlife-Highways Interaction Project. She obtained her B.S. in science education from Northern Arizona University and is currently working on an M.S. in forestry/wildlife focusing on the habitat factors associated with elk highway crossings.

Ray Schweinsburg has served as a research program supervisor for the Arizona Game and Fish Department for 12 years and has been involved with the Arizona State Route 260 Wildlife-Highways Interaction project since 2001. Mr. Schweinsburg has also been involved in extensive research in the Canadian arctic, including his work on polar bears.