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Advances in Wildlife Crossing Technologies

by *Mary Gray*

Researchers are deploying the latest tools to reduce animal-vehicle collisions and save the lives of both motorists and critters.



Crashes involving wildlife and vehicles are becoming a major safety concern. Wild animals, like this deer, are attracted to roadside vegetation, often putting them in harm's way.

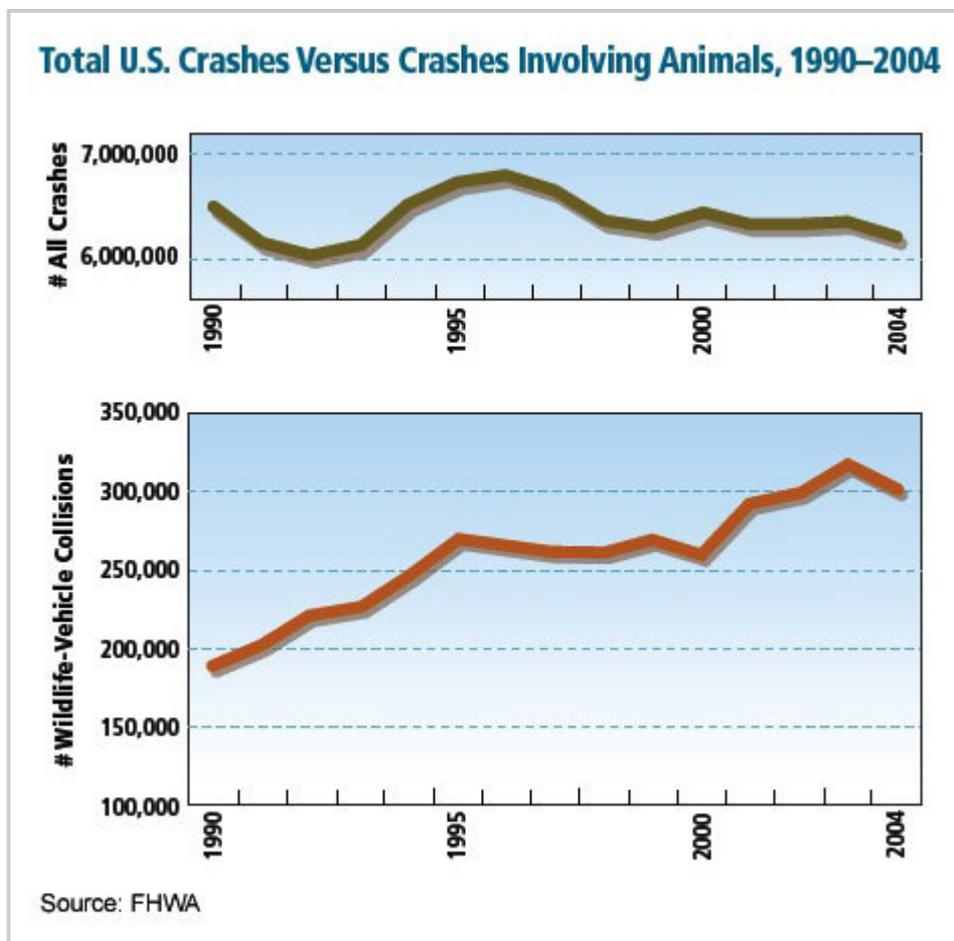
America's highways enable people and products to travel to every corner of the country. Along the way, these roads pass through the habitats of many wildlife species. Where roadways cross paths with foraging and migration routes, collisions occur--and in greater numbers than might be readily apparent.

According to the Federal Highway Administration (FHWA), the number of reported motor vehicle crashes between 1990 and 2004 held relatively steady at slightly more than six million per year. By contrast, the number of reported animal-vehicle collisions (including wildlife and domestic animals) increased by approximately 50 percent over the same period.

FHWA recently completed a study for the U.S. Congress looking at wildlife-vehicle collisions. According to *Wildlife-Vehicle Collision Reduction Study: Report to Congress* (FHWA-HRT-08-034), an estimated one to two million collisions occur each year between cars and

large, wild animals in the United States. This presents a real danger to human safety as well as the viability of some wildlife populations.

Wildlife-vehicle collisions can have a broad range of consequences for both people and animals. The most common results are wildlife mortality, vehicle damage, secondary motor vehicle crashes, and emotional trauma for motorists. A less direct impact is travel delays. Wildlife-vehicle collisions also can require the assistance of law enforcement personnel, emergency services, and road maintenance crews for repairs and carcass removal.



For animals, collisions with vehicles present an immediate danger to their individual survival. In addition, certain threatened and endangered species can face even greater reductions in their numbers, potentially affecting their ability to survive as a population. The FHWA study documents 21 federally listed threatened or endangered animal species in the United States for which road mortality is a threat to survival of the species or population.

Reducing these collisions continues to pose a challenge for the transportation community. According to the FHWA *Report to Congress*, "State and local transportation agencies are looking for ways to balance travel needs, human safety, and wildlife conservation."

Highway agencies already are using wildlife crossings, such as overpass and underpass structures, along with installation of fencing to restrict animals to using those structures and avoiding other long segments of roadway. But certain roadway conditions such as steep rocky slopes and deep snowpack are not always conducive to installing and maintaining wildlife crossing structures and fencing. To address the limitations of these traditional approaches, researchers are pushing forward with advances and deployments in three alternative areas: animal-vehicle detection systems, activated warning signs, and electric fencing and mats. Often these technologies can be combined at one location to enhance animal detection, alert drivers, and, most important, reduce collisions.

Animal Detection Systems

Animal detection systems use sensors to detect large animals as they approach the road. The two most common technologies for detecting animals in the roadway environment are area coverage sensors and break-the-beam sensors.



Marcel Huijser

This infrared, break-the-beam animal detection system is installed at a gap in a wildlife fence in the Netherlands.

Area coverage sensors detect large animals within the range of the sensor and can be either active or passive. Active coverage systems *send* a signal over an area and measure its reflection. Microwave radar is the primary technology used for active systems. Passive systems detect animals by only *receiving* signals. The two most common are passive infrared and video detection. These systems require algorithms that distinguish between moving vehicles with warm engines, moving pockets of hot air, and movements of large animals.

Detection Systems: Issues, Problems, and Operation

	Area Coverage	Break-the-Beam	Geophone	Radio Collar
False Positives				
High, moving, or wet vegetation	X	X		
Flying birds, nesting birds, rabbits	X	X		
Wind, rain, water, fog, snow spray, falling leaves	X	X	X	
Snow and ice accumulation on sensors or ground	X	(X)		
Microwave radio signal reflection off guardrail		X		
Sun, heat, unstable sensors	X	X	X	
Insufficient ventilation in box (fog on lens)	X	(X)		
Frost, low temperatures	X	X		
Lightning	(X)	X	X	(X)
Long distance between transmitter and receiver		X		
Traffic on road	X	X	(X)	
Traffic on driveways or side road	(X)	X		
Passing trains			X	
Signals from other transmitters		X		X
False Negatives				
Curves, slopes not covered by sensors	(X)	X		
Loitering animals in right-of-way not detected	(X)	X	(X)	
None of the individuals that cross have collars				X
Not feasible for nongregarious species/migrants				X
Insufficient warning time	(X)	(X)	(X)	
Some systems are only active during the night	X	X		
Maintenance				
Maintenance costs (e.g., mowing, power, fences)	(X)	X	(X)	(X)
Shade/snow on solar panels	(X)	X	(X)	(X)

Vandalism and theft (e.g., solar panels)	(X)	X	(X)	(X)
Safety (cars on road)	(X)	X	(X)	(X)
Broken sensors, warning lights, or other material	X	X	(X)	X
Period required to solve technical difficulties	X	X	X	X
Signs (standardization, liability)	X	X	X	X
No remote access to data (poor cell phone coverage)	(X)	X	X	(X)
Landscape, Ecology, Animals				
Landscape aesthetics	(X)	X	(X)	(X)
Animals' crossing areas may change over time	(X)	X	(X)	(X)
Animals may wander between fences (if present)	X	(X)	(X)	(X)
Small animals are not detected	X	X	X	X
Continuous effort to capture animals				X
Stress for the animals involved				X
Not in habitat linkage zones (light disturbance)			X	
<p>X = Problem has been reported or issue applies. (X) = Problem has not been reported, but it could occur. ¹For Swedish system that illuminates the road and right-of-ways once an animal is detected.</p> <p>This table shows that area coverage and break-the-beam systems seem to be particularly vulnerable to false positives and false negatives. Source: FHWA.</p>				

Break-the-beam sensors detect large animals when their bodies block or interrupt a beam of infrared, laser, or microwave radio signals sent between a transmitter and receiver.

The Colorado Department of Transportation (CDOT) is testing another sensor technology, known as intrusion detection, to reduce animal-vehicle collisions on U.S. 160 between Durango and Bayfield, CO. Military installations, prisons, airports, and some private landowners have used this particular technology for perimeter security, but its use in wildlife detection represents a new application.

The test zone consists of a cable buried 1 foot (30 centimeters) deep in the roadbed. The underground cable detects changes in the Earth's electromagnetic field caused when large animals such as deer, elk, and horses cross the cable. "When an animal enters the perimeter of the test zone, a sensor transmits the detection information to a control module that activates electronic signs to warn motorists of wildlife in the vicinity of the roadway," says Marcel Huijser, a researcher at the Western Transportation Institute in Bozeman, MT. Under a research grant with CDOT's Durango office, Huijser's team and a consulting company are collaborating to investigate the reliability and effectiveness of the system.

The installation consists of 12 signs (six on each side of the highway) in the test zone. When

an animal triggers the system, two signs for each direction of travel light up (the other signs are spaced out along the road). To avoid the problem of vehicles tripping the system when turning into and out of driveways, crews installed loop detectors in the pavement, like those that help ease traffic flow at signalized intersections. When vehicles drive over the loop detectors, the cable receives a message to ignore the crossing, and the signs will not light up.

Researchers also installed seven radar speed detectors to register motorists' speed when approaching the test zone and once inside it in order to monitor their base and reaction speeds. The radar system also will track traffic counts for followup analyses of the data. The researchers will download the data periodically and transmit the information to CDOT for review.

Other detection techniques include geophones that record vibrations in the ground when large animals approach, buried sensors that record changes in the electromagnetic spectrum when a large mammal walks by, and radio collars combined with receivers located in the roadway right-of-way.

According to the FHWA report *Best Practices Manual: Wildlife Vehicle Collision Reduction Study*, the effectiveness of animal detection systems in reducing collisions involving large mammals has been estimated at 82-91 percent, with an average of 87 percent. To ensure that the detection system functions reliably over time, the highway agency should establish a management plan that includes regular checks of the system's basic functions. Local personnel from the transportation or natural resource agency could perform these checks as part of their routine tasks. Remote access to the system via Internet or phone to download and check detection data, as well as data on battery voltage and output of solar panels, could help simplify this job. Periodic visits to the site still are necessary, however, to check on the functioning of the flashing warning lights and the continued correct positioning of the warning signs.

Other maintenance strategies might include a change in the management of the vegetation in the right-of-way (such as more frequent mowing or clipping), slower speeds for snowplows to avoid physical damage to the detection and warning systems from snow and ice spray, and replacing faulty, damaged, or missing equipment.

For these systems to be effective, road managers need to inform the traveling public about the purpose and location of animal detection installations. Signs placed upstream from the installations and messages transmitted via highway advisory radio are common ways to deliver the information to drivers.

In the future, this type of information might be delivered to onboard computers installed inside vehicles, which would automatically alert the driver through a warning signal when the vehicle comes within a certain radius of an animal detection system. This procedure would require a two-way, global positioning system-based communication system.



David Bryson, ElectroBraid

This solar-powered, animal-activated warning sign is part of an at-grade wildlife crosswalk near Payson, AZ. It warns approaching motorists when elk or deer are in the vicinity.

Pros and Cons of Animal Detection Systems

These systems are less restrictive to wildlife movement than fencing, and they allow animals to use existing paths to the road or to change them over time. Unlike wildlife crossing structures, which usually are limited in number and rarely wider than 164 feet (50 meters), animal detection systems have the potential to permit safer crossing opportunities for large wildlife anywhere along the outfitted roadway. Also, crews usually can install animal detection systems without major road construction or lengthy traffic control.

Some factors that affect installation time include whether fencing is part of the installation; whether roadwork is required, for example, to install a grate or electric mat; and how remote the site is. In terms of cost, these systems are likely to be less expensive than installing crossing structures, especially once the market demand grows and ushers in economies of scale through mass production. Because these technologies have not been extensively deployed and are still a relatively new approach, the cost of long-term maintenance is not known at this time.

Currently, these technologies only sense large animals, such as deer, elk, and moose. Smaller animals are harder to detect, and these systems do not warn drivers about their presence on or near the road. (There are many other solutions to minimize animal-vehicle collisions involving smaller animals, such as fencing, which is often combined with culverts to maintain habitat connectivity.) Some types of detection systems activate only in the dark, so animals crossing the roadway during daylight hours might not be perceived, leaving motorists with a false sense of security.

Environmental conditions and the size of the species can influence the reliability of animal detection systems. Road managers should consider the site carefully and the size of the target species before selecting a system. For example, break-the-beam sensors require unobstructed space between the sensors. Rocks, trees, or low-lying vegetation in between the sensors could lead to false readings.

For more information, see the combined FHWA/Montana Department of Transportation report *The Comparison of Animal Detection Systems in a Test-Bed: A Quantitative Comparison of System Reliability and Experiences with Operation and Maintenance* (FHWA/MT-09-002/5048), available at www.westerntransportationinstitute.org/documents/reports/4W0049_Final_Report.pdf.



Installation and Potential Applications

When installing animal detection systems, the sensor beams need to be set at the appropriate height for the species. For example, sensors for deer that are installed too close to the ground might detect small animals too, leading to false positives. In addition to system reliability, other factors to consider when choosing a detection system include robustness (that is, consistent performance over time and low monitoring and maintenance), size of the equipment (landscape aesthetics), and the length of road the sensors will need to cover.

DOTs can deploy animal detection systems as stand-alone mitigation measures or in combination with other strategies. Typical applications could include the following installations: (1) over relatively long road sections without wildlife fencing, (2) in a gap with extensive wildlife fences on either side, (3) in a gap with limited wildlife fences on either side aimed at funneling the animals toward the road section with the detection system, (4) at the end of extensive wildlife fencing, (5) at the end of extensive wildlife fencing aimed at funneling the animals through an underpass, and (6) along a low-volume road that parallels a high-volume road with an underpass.

Animal detection systems can reduce the number of collisions but cannot eliminate crashes completely because they still allow large animals to cross the road at grade. Nonetheless, as reported in the FHWA study [Best Practices Manual: Wildlife Vehicle Collision Reduction Study](#), available data suggest that these systems could reduce collisions to the level achieved through installation of wildlife crossing structures in combination with fencing, particularly in areas with low to moderate traffic densities.

Activated Warning Signs

Activated warning signs are another approach to help reduce animal-vehicle collisions. One type is the seasonal wildlife warning sign, which road managers install at certain times of the year when animals cross the road most frequently. Transportation and resource agencies have used activated warning signs during seasonal migrations and in high-crash locations, as well as in combination with animal detection systems.



Richard Lampman, ElectroBraid

This exclusion fencing for elk, deer, bear, moose, wolf, and coyote combines woven wire steel fencing at the bottom and electric fencing at the top.

A report by the Insurance Institute for Highway Safety, *Methods to Reduce Traffic Crashes Involving Deer: What Works and What Does Not*, describes a project in which researchers used large warning signs with battery-powered flashing amber lights at the ends of 2-mile (3.2-kilometer) and 4-mile (6.4-kilometer) roadway sections, together with smaller flashing signs at each milepost within the two sections. During three deer migration periods, when the signs were activated, the researchers found that travel speeds dropped about 8 miles per hour (13 kilometers per hour) from premigration levels. Also, deer-vehicle collisions dropped by 50 percent during the spring migration and 70 percent in the fall, compared with the three previous years.

Signs used in combination with other strategies can increase the effectiveness of efforts to minimize wildlife-vehicle crashes. For example, where animal detection systems are installed, once a large animal is detected, warning signals can be activated to inform drivers that an animal might be on or near the road. A downside to activated warning signs, however, is that drivers could become acclimated to them and choose not to use caution. Similarly, motorists might acknowledge the warning, but, if they do not actually see an animal, they could choose not to slow down, thereby negating the purpose of the signs.



Richard Lampman, ElectroBraid

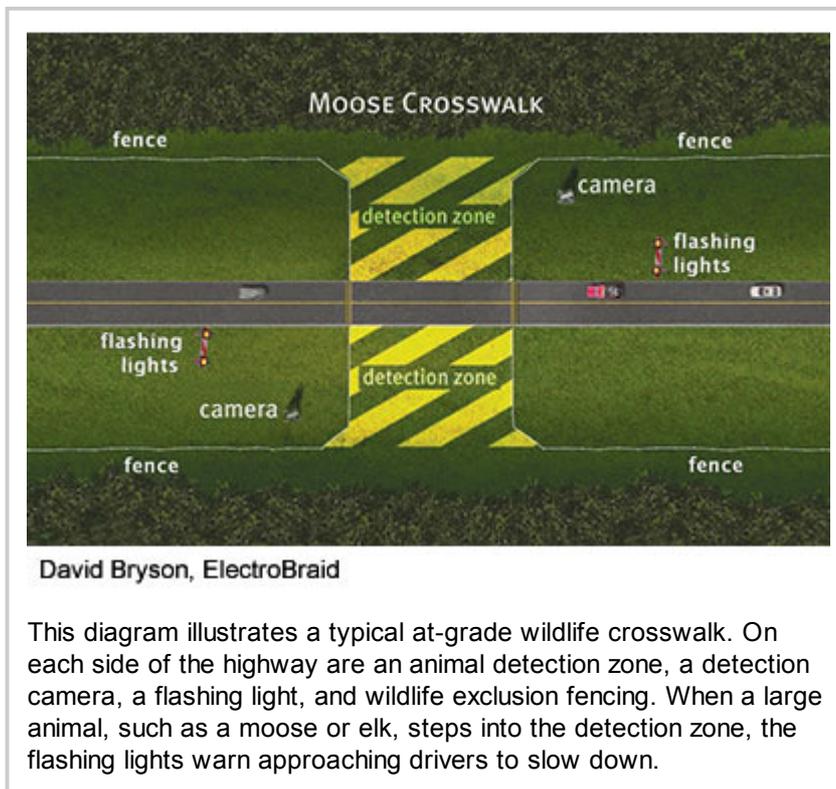
An electric mat like this one can seal off potential wildlife entry points at the ends of fenced sections, at access roads, or at driveways.

Electric Mats and Fencing

Another approach to reducing animal-vehicle collisions is installing electric fencing or mats.

Field trials by the National Park Service, State resource agencies, and others have shown that electric fencing can be an effective deterrent to a variety of animals including deer, elk, and bears. An animal investigates first with its nose and then receives a painful but harmless shock, deterring it from approaching the fence again.

Similarly, electric mats, embedded in the pavement or rolled across a low-volume road, can deliver a mild electric shock when animals step on them. Electric mats serve as an alternative to costly cattle guards. Pedestrians wearing shoes and bicyclists can cross the mats safely, but dogs, horses, and people without shoes will receive a mild electric shock. According to Norris Dodd, a senior natural resource specialist with AZTEC Engineering, pedestrian crossing buttons were installed at an installation in New Mexico, so people can deactivate the mats before crossing.



This diagram illustrates a typical at-grade wildlife crosswalk. On each side of the highway are an animal detection zone, a detection camera, a flashing light, and wildlife exclusion fencing. When a large animal, such as a moose or elk, steps into the detection zone, the flashing lights warn approaching drivers to slow down.

Electric fencing and mats can be cost-competitive with other types of wildlife fencing or even less expensive. For example, to exclude deer, agencies sometimes install regular fencing measuring an average of 8 feet (2.4 meters) high, and some fencing is buried up to 2 feet (0.6 meter) below the ground to prevent smaller animals from burrowing under it. Electric fencing, however, could require only 4- to 7-foot (1.2- to 2.1-meter)-high construction, depending on the species of wildlife involved, according to one fencing manufacturer. Pilot installations also reveal that routine maintenance needs are lower compared with traditional fencing, as the materials tend to be more durable and resistant to rust and weathering. Electric fencing also is less visible to motorists from the roadway, so it can be an aesthetically preferable alternative for use in scenic areas.

Bushes and tree branches pushing against the fencing and fallen tree limbs leaning on electric fencing or mats could drain the power, reducing the effectiveness of the systems. For that reason, maintenance crews should walk the perimeter of electric fencing at least once a year; electric mats also need to be cleared of snow, ice, and other debris. Although the products are designed not to be harmful to humans, signs should be posted to alert people to the potential hazard presented by electric fencing and mats, and deactivation buttons provide an option for people to turn them off before crossing.

Electric fencing can be used along highway rights-of-way to discourage wildlife from entering roads at unsafe locations. Electric mats could be installed on interstate ramps or near at-grade wildlife crossings. Agencies could combine either technology with animal detection systems and activated warning signs for more comprehensive applications.

Arizona Application In Preacher Canyon

In 2007, the Arizona Game and Fish Department, Arizona Department of Transportation (ADOT), FHWA, and U.S. Forest Service began a project to discourage elk and other wildlife from crossing the highway at grade along the Preacher Canyon section of State Route 260. The project aims to reduce the incidence of wildlife-vehicle collisions, while promoting wildlife highway permeability (allowing wildlife to move about freely). Researchers designed the project to integrate and evaluate the efficacy of several new technologies, including various retrofit fence designs and wildlife escape mechanisms (such as ramps, one-way trigger gates, and "slope jumps" built into the fence) to maintain the integrity of the fenced corridor. These escape mechanisms enable animals to exit the right-of-way when they inadvertently breach the fenced corridor. In particular, the study will assess the utility of animal detection systems integrated with motorist alert signage and electric fencing and mats to delineate a "wildlife crosswalk" as a potential alternative to building a costly wildlife passage structure.



Norris Dodd, AZTEC Engineering

An elk in the vicinity of this roadway in Preacher Canyon, AZ, triggered a nearby animal detection system, which, in turn, activated this variable message sign to alert motorists. The variable message sign is approximately 600 feet (180 meters) in advance of the wildlife crosswalk, which is located about where the car is.

After completion of a 2-year evaluation following implementation, results indicate that the project has reduced the incidence of elk-vehicle collisions by 96 percent in the Preacher Canyon area, with only one elk-vehicle collision in 2.5 years compared to 12 collisions per year from 2001-2006. In addition, the reaction from motorists in terms of reducing speed and applying brakes in response to the warning signs and crosswalk concept has been significant. "The system detected animals approaching the highway and activated the motorist alert signs 97 percent of the time, including the initial period where the bugs were being worked out," says Dodd, who was a leading proponent for habitat connectivity and decreasing wildlife-vehicle collisions while working as a research biologist at the Arizona Game and Fish Department. "We are seeing very few false positives."

Best Practices Manual

FHWA recently completed and posted online a comprehensive [Best Practices Manual: Wildlife Vehicle Collision Reduction Study](#) as a followup to the November 2007 study and report to Congress on wildlife-vehicle collisions. Congress mandated the study, report, and best practices manual in 2005 under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users.

The best practices manual covers the complete range of strategies for reducing wildlife-vehicle collisions, from statewide and regional planning through site-specific mitigation. The document includes the following features:

- Regional and statewide tools important to wildlife-vehicle collision reduction, specifically for statewide data collection plus identification of regional priority locations.
- Guidance on incorporating collision reduction measures into roadway design by consideration of alternate alignments, possible adjustments in elements of highway design, and identification of crossing locations for mitigation efforts.
- Guidance on reducing collisions involving large animals and threatened and endangered species.
- Guidance on monitoring and evaluating collision mitigation practices.
- Checklist for implementing a collision reduction program.
- List of potential funding sources.

The manual provides design and implementation guidelines for wildlife fencing, wildlife underpasses and overpasses, animal detection systems, vegetation management, and wildlife culling.

To access *Best Practices Manual: Wildlife Vehicle Collision Reduction Study*, visit www.fhwa.dot.gov/environment/hconnect/wvc/index.htm.

At first, Dodd expected that getting motorists to respond to the activated signage would be difficult. However, motorist speeds dropped significantly—by 16 percent, or 9 miles per hour, mi/h (15 kilometers per hour, km/h)—when the signage was activated, and nearly 70 percent of all motorists showed increased alertness by applying their brakes, thus increasing their ability to avoid collisions. "Achieving this motorist response to the signage was critical to making the animal detection system and crosswalk the success it has been," Dodd says.

The lone aspect of the Preacher Canyon project that proved problematic was the proportion of animals (20 percent) that traveled around the end of the crosswalk fencing and into the fenced right-of-way along the roadway. Fortunately, no crashes resulted from this behavior while the animals fed along the roadside before returning to the end of the crosswalk zone. Although an electric mat was installed as part of the project on a low-volume lateral access road, Dodd says ADOT has approved the installation of an electric mat in the highway to discourage animals from leaving the crosswalk and walking parallel to the highway. This will be the first application of an electric mat on a relatively high-volume highway (with an average annual daily traffic volume of 8,000).

According to Jeff Gagnon, a research biologist with the Arizona Game and Fish Department, "the crosswalk and fencing will remain in place for an additional 3 to 4 years, until the site is upgraded similarly to the four-lane divided section of Preacher Canyon, allowing us to continue to evaluate the project."



Norris Dodd, AZTEC Engineering

Researchers installed this sign in Preacher Canyon, AZ, to alert motorists that they are approaching the wildlife crosswalk testing area. This sign is located approximately 1,200 feet (366 meters) from the crosswalk.

Checklist for Program Implementation

As outlined in the FHWA report to Congress and a companion document highlighting best practices (see "Best Practices Manual" on page 20), a variety of approaches and techniques are available to help prevent and minimize collisions between vehicles and wildlife. Research and field trials of advanced warning signs, animal detection systems, and electric fencing and mats have proven successful under certain conditions. But success hinges on highway and resource agencies installing the devices in suitable locations, according to manufacturer's guidance, and targeting appropriate species. And the systems need to be maintained properly.

In the future, roadside animal detection systems also might transmit warning signals via in-vehicle systems to traffic approaching a location where a large animal has been detected on or near the road. With deployments of animal detection systems becoming more numerous, future research might require development and acceptance of standards for communication and integration of intelligent transportation systems.

For agencies seeking to launch programs to reduce wildlife-vehicle collisions, FHWA offers the following checklist of steps.

Establish a multiagency coalition to oversee the program. The makeup and structure of the oversight committee should be tailored to include appropriate agencies and to integrate the program within the organizational structures of the partner organizations.

Determine the baseline magnitude of the problem for the State, such as data on the annual number of collisions and crashes involving threatened and endangered species.

Implement a statewide data collection and monitoring plan and identify regional priority locations.

Establish annual goals and potential funding sources, which might include various Federal, State, and local funds as well as contributions from private foundations or corporate partners.

Identify specific improvements and mitigation strategies.

Educate State DOT staff and incorporate consideration of wildlife-vehicle collisions into the highway design process.

And establish a program to evaluate and monitor the effectiveness of specific mitigation efforts.

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To access Wildlife-Vehicle Collision Reduction Study: Report to Congress (FHWA-HRT-08-034), visit http://www.wti.montana.edu/RoadEcology/documents/Wildlife_Vehicle_Collision_Reduction.pdf. For more information, contact Mary Gray at 360-753-9487 or mary.gray@dot.gov.

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