PANEL SESSION PRESENTATION

A DECADE OF PROACTIVE PROGRESS IN RESOLVING ARIZONA HIGHWAY-WILDLIFE CONFLICTS

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ABSTRACT

Arizona first captured the road ecology community’s attention in 2002 when the first 2 State Route (SR) 260 wildlife underpasses were completed. Arizona’s efforts to resolve conflicts between wildlife and highways and to promote connectivity have since expanded dramatically in both scope and scale, yet the Arizona Department of Transportation (ADOT) and its partners face new challenges. This paper provides an overview of these efforts and addresses emerging issues that will challenge road ecologists and transportation managers in sustaining this progress.

Construction and Retrofitting: The phased reconstruction of SR 260 with 11 wildlife underpasses is nearly complete; its high-profile status was eclipsed by the US Highway 93 (US 93) reconstruction project with 3 wildlife overpasses targeting desert bighorn sheep (Ovis canadensis) connectivity. Reconstruction along SR 68 also addressed bighorn permeability with 3 underpasses and fencing. All 3 of these comprehensive “big projects” were planned to address landscape-scale connectivity. However, with major construction funding dwindling, retrofitting highways during smaller widening projects to address wildlife needs will likely increase in importance over the next decade. Retrofitting that utilizes existing structures suitable to accommodate wildlife passage and address wildlife-vehicle collision (WVC) “hotspots” when integrated with fencing holds considerable potential. Such an approach has been pursued on 2 highways in Arizona along with innovative and cost-effective designs, applications and products. With existing suitable structures not present or adequately spaced, new “drop-in” structures (e.g., precast arch underpasses, overpasses) on widening projects is currently being pursued on 2 highways: the state’s first 2 “drop-in” underpasses along SR 86 with the Tohono O’odham Nation, and on SR 77 with an overpass, underpass, and fencing linking them to 3 existing large bridges. These projects are funded by the Pima County Regional Transportation Authority, a model for sustainable funding that commits $45 million over 20 years to wildlife connectivity.

Research: ADOT has funded 20 separate research projects since 2002, including intensive research along 5 highways to monitor and enhance project effectiveness. Intensive research projects were funded along 10 highways to develop data-driven strategies to address WVC and
permeability for future reconstruction planning and design. This research has contributed to the understanding of road ecology relationships, fostered development of new technologies, and increased agency and public awareness.

**Linkage Assessments:** Since completing the landmark 2006 *Arizona’s Wildlife Linkages Assessment* identifying 152 linkages statewide, 4 refined county-level linkage assessments and 21 individual linkage modeling assessments have been completed. These assessments are being integrated into ADOT’s transportation improvement plans, and planning is ongoing to guide and streamline evaluation and implementation of strategies to promote connectivity.

**Litigation:** In 2003, the state was found negligent in the *Booth v. State of Arizona* case after a motorist hit a dead elk (*Cervus elaphus*) along I-40, raising concerns regarding liability associated with WVC and ADOT’s role in preventing them; this decision was upheld on appeal. In 2012, the state mounted a successful defense to similar claims by a motorcyclist that hit a dead elk along SR 260 in the *Sayer v. State of Arizona* case; this affirmative outcome reflected ADOT’s comprehensive commitments to reducing WVC and promoting connectivity since 2003.

**Maintenance:** With the growing number of projects integrating measures to address WVC and connectivity, ADOT developed a database and protocol to complete an inventory and condition assessment of all statewide wildlife “assets” employing its GIS-based Features Inventory System. This information is being used to develop short- and long-range programs to fund and maintain functionality of its growing asset inventory.

**INTRODUCTION**

Arizona’s population growth has been one of the highest in the U.S. for two decades. Between 1990 and 2000, Arizona’s population growth rate (40%) was the second highest among all states based on U.S. Census data, and the state is projected to remain a national growth leader in the coming decade. Along with this growth comes increasing demands placed upon the state’s highway transportation infrastructure associated with higher traffic and potential safety issues. This growth also exacerbates the conflict between vehicles traveling Arizona’s highways and wildlife. The state possesses tremendous landscape diversity with correspondingly high diversity of wildlife species and types of conflicts they encounter along our highways. Such conflicts with wildlife range from WVC involving large ungulates like elk, mule deer (*Odocoileus hemionus*) and bighorn sheep, reduced highway permeability due to high and increasing traffic volume affecting species like pronghorn (*Antilocapra americana*), to vehicle-related mortality to sensitive reptiles like the desert tortoise (*Gopherus agassizii* and *G. morafkai*) and flat-tailed horned lizard (*Phrynosoma mcallii*) that impact population viability.

While road ecology was gaining scientific credibility as a discipline in North America during the late 1990s (Forman et al. 2003), partly due to landmark measures to address WVC and promote permeability in Banff National Park in Alberta and research evaluating the efficacy of the measures (Clevenger and Waltho 2000), similar efforts in Arizona before 2000 appeared to be nonexistent. Arizona did not participate in the 2000 nationwide survey and synthesis of highway practices involving the interaction between roadways and wildlife (NCHRP Synthesis 305; Transportation Research Board 2002). This contributed to the impression that little activity relative to resolution of highway-wildlife conflict was occurring beyond the application of roadway warning signage. In reality however, refined project planning and environmental
analysis for the SR 260 reconstruction project that would subsequently gain international acclaim for its comprehensive approach to addressing permeability and WVC were well underway in the late-1990s (ADOT 2000). And with completion of the first phase of construction there in 2002 and monitoring of wildlife use of its first two wildlife underpasses (Dodd et al. 2007a), Arizona was vaulted into the road ecology limelight. Since then, Arizona, ADOT, and its numerous partners have embarked on a sustained and committed course toward implementing a comprehensive strategy to proactively resolve highway-wildlife conflicts. This paper provides an overview of these diverse efforts and some of the key insights gained over the last decade. It also describes how emerging transportation issues will challenge ADOT and its partners to adapt in order to sustain our collective progress in helping make Arizona’s highways more wildlife and environmentally friendly.

OVERVIEW OF PROGRESS MADE SINCE 2000

The “Big-Project” Era

Initial reconstruction efforts along SR 260 not only vaulted Arizona into a road ecology leadership role, they also ushered the state into an unparalleled period of extensive reconstruction of three different highways that addressed wildlife issues. Each project incorporated comprehensive strategies to resolve highway-wildlife conflicts, focusing on addressing connectivity from a landscape-scale perspective. These high-profile projects did much to increase agency and public awareness of road ecology and even helped foster agency cultural change (Dodd and Gagnon 2010). Similar new “big projects” likely will not occur over the next decade due to declines in transportation funding, presenting a challenge to sustain Arizona’s proactive connectivity efforts.

State Route 260

The SR 260 project in central Arizona has been considered a premiere example of ADOT’s efforts to reduce WVC and promote wildlife connectivity and highway permeability; this project was conferred one of FHWA’s first Exemplary Ecosystem Initiative awards in 2004. SR 260 crosses through some of Arizona’s best elk habitat, as the original highway alignment traversed numerous wet meadow and riparian/stream habitats. The historic incidence of WVC was a significant issue being addressed by the reconstruction as well as landscape connectivity and permeability across the widened 4-lane divided highway. Since 2000, ADOT has been engaged in the phased reconstruction of this 28-km (17-mi) stretch of highway under five separate programmed projects, with the last to be completed in 2013. The fully completed project will incorporate 11 wildlife underpasses and six large bridges that along with fencing to funnel ungulates to the passage structures have already proven successful in reducing the incidence of WVC by as much as 97% (Dodd et al. 2012, Gagnon et al. 2010), and promoting permeability for elk (Dodd et al. 2007b, 2012), white-tailed deer (O. virginianus; Dodd and Gagnon 2011), and other species. SR 260 has served as a “living laboratory” for new and innovative wildlife measures and applications (Dodd et al. 2010, Gagnon et al. 2010). Nearly 10 years of continuous and rigorous ADOT-funded research with video camera monitoring of underpasses through which 11 different species passed, GPS telemetry to quantify permeability, and WVC documentation across construction phases fostered construction adaptive management and added substantially to our understanding of road ecology relationships (Dodd et al. 2007a, 2012).
State Route 68
SR 68 links US 93 from a point just north of Kingman to Nevada, in northwestern Arizona. A 23-km (14-mi) stretch was realigned and widened to a 4-lane divided highway between 2000 and 2002. As part of the reconstruction, three wildlife underpasses were constructed and integrated with ungulate fence. SR 68 cuts through the southern end of the Black Mountains (figure 1), habitat for one of Arizona’s premier desert bighorn sheep populations. The underpasses and wildlife fencing were constructed to address WVC involving bighorn sheep and to promote habitat connectivity and permeability for bighorn crossing SR 68. This was the first highway to address bighorn-highway conflicts; along with the later US Highway 93 reconstruction, these projects embodied a landscape approach to preserving connectivity across the Black Mountains (figure 1). Post-construction monitoring of the effectiveness of the underpasses was conducted between 2005–2007, with limited use of the underpasses by bighorn due largely to underpass placement deficiencies (Bristow and Crabb 2008).

Figure 1. The Black Mountains of northwest Arizona, fragmented into three subunits by US 93 and SR 68 where comprehensive connectly strategies have been implemented.

US Highway 93
Following nearly a decade of major highway realignment and reconstruction activities, including the accelerated Hoover Dam Bypass project following the September 11, 2001 terrorist attacks, US 93 is now arguably Arizona’s premier example of efforts to address wildlife connectivity. As part of the highway reconstruction to a 4-lane divided highway along 28 km (17 mi), completed in 2011, ADOT addressed wildlife connectivity objectives with construction of three wildlife overpasses (figure 2) and three large bridges (underpasses), linked with ungulate fencing. The ultimate construction of these structures reflected a long-term commitment made to assessing
wildlife movement patterns to facilitate data-driven selection of passage structure locations (Cunningham and Hanna 1992, McKinney and Smith 2007), the first of several highways employing this approach by ADOT (see research section). Overpasses were recommended based on bighorn preference for traveling along ridgelines (McKinney and Smith 2007) and to address limited sheep use of underpasses along SR 68 (Bristow and Crabb 2008). US 93 traverses the northern extent of the Black Mountains (figure 1) and passage structures and fencing were constructed to address WVC involving bighorn sheep, especially in the vicinity of the Colorado River, and to promote landscape connectivity and permeability across the highway (figure 1).

During-construction evaluation of highway construction impact to bighorn sheep was accomplished (Gagnon et al. 2011), and post-construction monitoring of bighorn sheep use of passage structures, highway permeability, and WVC incidence involving bighorn is ongoing by the Arizona Game and Fish Department (AGFD). This monitoring has recorded substantial bighorn sheep use of the overpasses, and has also resulted in adaptive management modifications to other wildlife measures (e.g., escape ramps, access controls).

Figure 2. One of three wildlife overpasses along US 93 to promote desert bighorn sheep highway permeability and landscape connectivity; located at MP 3.3, looking northeast.

ADOT Commitment to Research

Since 2002, ADOT has sustained a strong commitment to rigorous research into highway-wildlife relationships, now accomplished along 11 different highways and just begun on a twelfth (table 1). This research has been accomplished under 20 separate cooperatively ADOT-funded projects conducted by AGFD (table 1). Research along three of the highways (I-17, SR 260, and US 93) is now considered long term in nature, ongoing continuously for six years or more and evaluating various construction phases under Before-After-Control Impact experimental designs (Hardy 2003, Roedenbeck et al. 2007). Most (18) of the research projects were funded and administered by ADOT’s Research Center, with two funded as part of construction planning (I-15, I-40). The overall purpose of the various ADOT-funded research projects have fallen into three categories (table 1):
- Effectiveness monitoring of wildlife measures (e.g., underpasses, overpasses, fencing) and support for adaptive management and continuous improvement (5 highways).
- Development of data-driven recommendations for passage structure locations/types and fencing on future projects (10 highways).
- Development and evaluation of new technologies and applications (4 highways).

Table 1. Highways (and the number of separate projects along each highway) funded by ADOT, including focal wildlife species, general purpose of the projects, and final ADOT report citations.

<table>
<thead>
<tr>
<th>Highway (No. Projects)</th>
<th>Focal Wildlife Species*</th>
<th>General Purpose of Research Project(s)</th>
<th>Final ADOT Report Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR 64* (1)</td>
<td>Elk</td>
<td>X</td>
<td>Dodd et al. (2012)</td>
</tr>
<tr>
<td>SR 68 (1)</td>
<td>Bighorn sheep</td>
<td>X</td>
<td>Bristow and Crabb</td>
</tr>
<tr>
<td>SR 95 (1)</td>
<td>Desert tortoise</td>
<td>X</td>
<td>Grandmaison</td>
</tr>
<tr>
<td>SR 260* (5)</td>
<td>Elk</td>
<td>X</td>
<td>Dodd et al. (2007a)</td>
</tr>
<tr>
<td></td>
<td>White-tailed deer</td>
<td>X</td>
<td>Dodd et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>Mule deer</td>
<td>X</td>
<td>Gagnon et al. (2010)</td>
</tr>
<tr>
<td>US 89* (2)</td>
<td>Pronghorn</td>
<td>X</td>
<td>Dodd et al. (2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Theimer et al. (2012)</td>
</tr>
<tr>
<td>US 93* (3)</td>
<td>Bighorn sheep</td>
<td>X</td>
<td>McKinney and Smith</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gagnon et al. (2011)</td>
</tr>
<tr>
<td>US 93 (1)</td>
<td>Desert tortoise</td>
<td>X</td>
<td>Grandmaison</td>
</tr>
<tr>
<td>US 180* (1)</td>
<td>Elk</td>
<td>X</td>
<td>Gagnon et al. (2011)</td>
</tr>
</tbody>
</table>

*Research projects with consistent GPS telemetry applications and ADOT-installed traffic counters
On seven of the highways where research was conducted (with research on an 8th just begun), consistent methodologies (Dodd et al. 2007b) were applied to conduct GPS telemetry assessments of highway permeability for 5 different ungulate species (table 1). On all of these highways, ADOT installed automatic traffic counters to provide bi-hourly traffic volume data to correlate to GPS data and allow for empirical assessment of relationships between wildlife highway permeability and traffic (Gagnon et al. 2007a). For five of the seven highways where the purpose of the research was to develop recommendations for wildlife passage structures and fencing for future construction, a total of 63 passage structures and nearly 400 km (248 mi) of ungulate fence were recommended (table 2).

Table 2. Arizona highways where research was conducted to develop data-driven recommendations for wildlife passage structures and ungulate fencing, focal wildlife species for which GPS telemetry was done, the number of recommended passage structures and mean spacing between structures, and length of recommended associated ungulate fence.

<table>
<thead>
<tr>
<th>Highway</th>
<th>Focal species</th>
<th>Length (km)</th>
<th>Recommended Passage Structures</th>
<th>Mean structure spacing (km)</th>
<th>Ungulate fencing (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US 89</td>
<td>Pronghorn</td>
<td>27.5</td>
<td>- 3</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>SR 64</td>
<td>Pronghorn</td>
<td>92.3</td>
<td>9 2</td>
<td>7.1</td>
<td>46.0</td>
</tr>
<tr>
<td></td>
<td>Elk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mule deer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-17</td>
<td>Elk</td>
<td>74.5</td>
<td>14 5</td>
<td>3.5</td>
<td>109.2</td>
</tr>
<tr>
<td></td>
<td>Mule deer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-40</td>
<td>Elk</td>
<td>93.3</td>
<td>15 5</td>
<td>4.2</td>
<td>174.3</td>
</tr>
<tr>
<td></td>
<td>Mule deer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR 260</td>
<td>Elk</td>
<td>36.3</td>
<td>10 0</td>
<td>3.0</td>
<td>70.4</td>
</tr>
<tr>
<td></td>
<td>Mule deer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>324.1</td>
<td>48 15</td>
<td>5.1</td>
<td>399.9</td>
</tr>
</tbody>
</table>

Connectivity and Linkage Assessments

To help preserve and restore landscape connectivity and develop comprehensive plans to proactively address connectivity (Beier and Loe 1992), numerous states have completed statewide connectivity assessments. Arizona’s connectivity and linkage assessments have been accomplished at three scales: 1) the statewide Arizona’s Wildlife Linkage Assessment, 2) refined county-level assessments, and 3) individual linkage design modeling assessments.

Statewide Connectivity Assessment

The Arizona's Wildlife Linkages Assessment (Arizona Wildlife Linkages Workgroup 2006) was completed in 2006, representing the results of a comprehensive analysis and stakeholder workshop in which 152 potential wildlife linkage zones were identified, rated and prioritized (figure 3). This assessment, endorsed by both ADOT and FHWA leadership, was intended to
provide a starting point for detailed consultation and coordination among the various organizations and agencies that have responsibility and interest in preserving habitat connectivity. The potential linkage zones were identified from various map overlays including land ownership, undeveloped habitat blocks, vegetation types; expert opinion of workshop participants was used to define fracture zones between habitat blocks and to identify corresponding linkage zones. As part of the statewide linkage assessment, each identified linkage zone was prioritized based on its relative biological and corresponding threat/opportunity value (Arizona Wildlife Linkages Workgroup 2006). Based on the prioritization of biological and threat/opportunity values, 28 of the linkage zones were identified as “top priorities” for attention (Arizona Wildlife Linkages Workgroup 2006).

**County-Level Linkage Assessments**
Subsequent to the statewide assessment, county-level wildlife connectivity assessments were begun with a goal of refining the identification of wildlife linkages. The county-level assessments assembled current knowledge of linkages and barriers to wildlife movement while helping build collaborative partnerships with local jurisdictions for implementation efforts. Each county assessment report and its associated GIS data is intended to identify wildlife linkages at a finer scale or that may have been overlooked in the statewide assessment and that will be useful for regional and local planning efforts. Development of county level connectivity assessments is ongoing for four Arizona counties: Apache/Navajo, La Paz, and Yavapai counties, and has been completed for four counties: Coconino (AGFD 2011), Maricopa (AGFD 2012a), Pima (AGFD 2012b), and Pinal (AGFD 2013).

**Linkage-Level Corridor Modeling**
Individual linkage-scale corridor design assessments and modeling have been accomplished across Arizona by both Northern Arizona University (NAU) and AGFD. These refined linkage designs identified and mapped multi-species **corridors** that best maintain wildlife movements between wildland blocks (Figure 4), as well as highlight specific planning and road mitigation measures required to maintain connectivity within these corridors. Linkage-level assessments were accomplished utilizing the computer-aided GIS modeling and mapping tools at [www.corridordesign.org](http://www.corridordesign.org) (Beier et al. 2008). NAU has completed detailed linkage designs for 16 priority linkages identified in the *Arizona’s Wildlife Linkages Assessment* (Arizona Wildlife Linkages Workgroup 2006) now found at [www.corridordesign.org/linkages/Arizona](http://www.corridordesign.org/linkages/Arizona). AGFD has completed detailed linkage designs for an additional four priority linkages, and is working on others. These reports may be accessed at [www.azgfd.gov/wc/documents](http://www.azgfd.gov/wc/documents).

**Seizing Opportunities for Retrofitting/ Commitment to Innovation**
Even as the “big projects” along SR 260, SR 68, and US 93 were ongoing with their extensive wildlife measures, ADOT and AGFD cooperated to seek out short-term solutions along highway stretches where WCV “hotspots” were evident, integrating ungulate fencing with existing suitable bridges and other structures that had the potential to function as effective wildlife passages. While taking a proactive stance in pursing projects to resolve highway-vehicle conflicts outside of the normal project planning process utilizing the enhancement grant process afforded by TEA-21, ADOT, AGFD and FHWA also embraced the opportunity presented by these projects to try (and evaluate via AGFD research) new and innovative technologies, applications and products for use in future projects.
Figure 3. Map of the 152 linkage zones and associated habitat blocks identified in the Arizona’s Wildlife Linkages Assessment (large map), and an enlarged view (right) of the linkage zones identified in the Coconino County area around Flagstaff that correspond to the shaded inset on the statewide map.
SR 260 Preacher Canyon Wildlife Fencing and Crosswalk Enhancement Project
The first such project occurred along the 5-km (3-mi) Preacher Canyon Section of SR 260, the first of the five reconstructed highway sections. The original reconstruction of the section from a 2-lane to a 4-lane divided highway included limited ungulate fencing (<0.4 km) near two wildlife underpasses at the section’s eastern end. A high number of crossings by GPS-collared elk and elk-vehicle collisions (EVC) continued to occur along the unfenced portion of section following reconstruction (Dodd et al. 2007a); EVC incidence after reconstruction (mean = 11.7 EVC/year) was higher than the before-reconstruction mean of 9.7 EVC/year; wildlife underpasses and limited fencing were not promoting motorist safety (Dodd et al. 2007c).

With insights from strategically fencing the next highway section using elk GPS crossing data (Dodd 2007b) to intercept elk at peak crossing areas, resulting in an 85% reduction in EVC and a 53% increase in permeability (Dodd et al 2007c), AGFD submitted a TEA-21 enhancement grant for the Preacher Canyon Section. The project was intended to similarly reduce the incidence of at-grade elk highway crossings and EVC, with right-of-way (ROW) fence along 10.5 km (6.5 mi) raised to 2.4 m (8 ft) to make the fence impermeable to elk and to funnel animals toward the Preacher Canyon Bridge and two existing wildlife underpasses. Cost-effective retrofit fencing designs were utilized including extended barbed-wire T-posts and electric fence energized by both AC and DC power (Dodd et al. 2010). At the west end of the section, where no passage structure or impassable topographical feature existed where the fence could effectively be terminated, an experimental animal detection system was installed to prevent an “end-run” effect.
(e.g., Clevenger et al. 2001) where wildlife could pass around the end of the fence. The detection system was configured such that a defined wildlife “crosswalk” was created with radio-activated warning signage to alert motorists when animals attempted to cross. The project was implemented in early 2007 and evaluation of its effectiveness has been ongoing since (Dodd et al. 2010, Gagnon et al. 2010). An electrified mat was later installed as an alternative to a cattle guard across SR 260 to prevent encroachment of animals into the fenced corridor. All project elements including the crosswalk components and fencing have remained functional, and EVC have been reduced 97% since implementation (figure 5). The Western Transportation Institute (WTI; Huijser et al. 2007) determined the total costs associated with EVC ranging from vehicle property damage and human injuries and fatalities to removal and disposal of to be $18,561. Thus, the annual benefit from reduced EVC with the Preacher Canyon fencing project is estimated at $37,000/km/year; this benefit covers the costs for the entire enhancement project in just four years. The animal detection system, crosswalk, and alert signage have proven effective in resulting in significantly modified motorist behavior and preventing WVC associated with the anticipated “end run” (Dodd, et al. 2010, Gagnon et al. 2010).

![Figure 5. Annual frequency of EVC along the Preacher Canyon Section of SR 260 before (2001–2006) and after (2007–2012) the fencing and crosswalk enhancement project was implemented (from Gagnon et al. 2010).](image)

**I-17 Munds Park Wildlife Fencing Enhancement Project**

Inspired by the success of the SR 260 fencing project, AGFD and ADOT evaluated options for similar retrofitting along I-17 south of Flagstaff. A 10-km (6-mi) stretch near Munds Park accounted for 28% of all WVC along 55 km (35 mi) of interstate, and possessed suitable structures that could serve to promote wildlife passage across the highway, including two large bridges. ROW fencing was extended to 2.4 m (8 ft) in height for the full length between the bridges, which were 8 km (5 mi) apart - excessive spacing to adequately promote wildlife passage. Consequently, with the retrofitting of two traffic interchanges (TI) as dual-use crossings between the bridges, spacing was reduced to a desirable 2.1 km (1.3 mi). To allay safety concerns associated with dual vehicular and wildlife use, AGFD found that the
preponderance of elk activity near the TI occurred during very low-traffic nighttime hours. Retrofitting a TI underpass for wildlife use was easy, simply running funnel fencing into the structure abutments, and except for its narrower width (and paved floor), this structure is similar to effective wildlife underpasses elsewhere. However, retrofitting a TI overpass for wildlife use posed a considerably greater engineering challenge, requiring new concrete cast-in-place pedestrian parapets and reinforced screening fence atop the parapet to complete the retrofit (figure 6), still at a fraction of the cost of a new overpass. Another innovative element of this enhancement project was the use of eight 1.2 m (4 ft) wide solar-powered electrified mats installed flush with the pavement surface in place of cattle guards along on- and off-ramps; motorists were sliding through the cattle guards at stop bars during winter due to ice and snow. Crosswalk-type push button switches were installed at the mat sites to temporarily cut power to prevent shock to crossing pedestrians. AGFD researchers are now evaluating the efficacy of the enhancement project completed in 2011, using video cameras to monitor wildlife use of the four retrofitted wildlife crossings. To date, after 18 months, no EVC have been recorded, a dramatic reduction from the average 15.5 EVC/year before implementation. This reduction in EVC equates to a $28,000/km/year benefit from reduced EVC that will “pay” for the project in just five years using the WTI costs for EVC.

Figure 6. Retrofitted dual-use overpass along I-17 (Fox Ranch Road) with new parapet walls and reinforced fencing to accommodate wildlife passage.

Cementing a Commitment - Legal Challenges

In 2002, the State of Arizona was found negligent in the Booth v. State of Arizona case by Pima County Superior Court for injuries suffered by a motorist that hit a dead elk on I-40 in 1998, and paid a substantial judgment. The Arizona Court of Appeals, in its 2004 affirmation of the lower court’s jury ruling, found that the long-held doctrine of ferae naturae (wild animals exist through nature and are not predictable or controllable, therefore are neither the property nor responsibility of the State) did not limit liability on the State’s part for the acts of wild animals in claims of negligence. The Court of Appeals found that the State breeched its duty to keep its roadways
reasonably safe for travel, and failed to guard against foreseeable collisions between vehicles and wildlife. At the time of the trial, ADOT was engaged in ongoing highway reconstruction along SR 68 and the early phases of SR 260, the first of its projects expressly addressing WVC and wildlife connectivity issues. Thus, the State had a limited track record in resolving highway-wildlife conflicts and had yet to develop a comprehensive statewide program. And while it is important to stress that the Booth case was not the impetus for the comprehensive wildlife measures implemented on the SR 260 and SR 68 (or other) projects, both planned years in advance of the case, it nonetheless underscored the importance of addressing wildlife issues in a comprehensive and proactive manner and helped to cement ADOT’s commitment to doing such.

In a strikingly similar incident in 2009, a motorcyclist traveling on SR 260 hit a dead elk along the roadway and sustained injuries, resulting in the Sayer v. State of Arizona case. This case went to trial before a jury in Gila County Superior Court in 2012. Part of the State’s defense was built around the substantial progress that had occurred in the decade since the Booth case relative to comprehensive and integrated efforts to address highway-wildlife conflicts. These efforts included ADOT construction and retrofitting projects that addressed highway-wildlife conflicts, ADOT-funded research, and other activities such as wildlife-vehicle collision reduction studies commissioned by ADOT and the Arizona’s Wildlife Linkages Assessment (figure 7). In this case, the jury ruled that the State was not negligent in contributing to the accident. Though the case remains under appeal, it further underscores not only the importance of, but also the benefit of ADOT’s comprehensive efforts to resolve highway-wildlife conflicts.

Figure 7. Arizona highways where ADOT highway projects addressing highway-wildlife conflicts (black dots), ADOT-funded research (red dots), and wildlife-vehicle collision reduction studies (green dots) were accomplished or planned in 2002 (left) compared to 2012.
ADOT Focus on Maintaining its Wildlife Asset Inventory

Over the past decade, ADOT has implemented numerous projects to resolve highway-wildlife conflicts. Additional future projects with many wildlife elements are planned for implementation. However, with the number and diversity of its wildlife assets growing, ADOT is now faced with the challenge of performing regular maintenance to ensure the functionality of its wildlife assets, especially under increasingly limited maintenance budgets. Maintenance of these assets is essential to meeting their intended biological purpose of mitigating highway impacts to wildlife and promoting highway safety via reduced WVC. Failure to adequately maintain some assets such as ungulate fence may contribute to hazardous situations as animals that breach the fenced corridor can become trapped, causing WVC. Thus, there is a growing need to both track the growing inventory of wildlife assets being implemented across the state and to develop an approach to assess the condition of these assets and ensure that needed maintenance is accomplished.

ADOT pursued development of a database to inventory its diverse wildlife assets and to assess current condition and maintenance needs. The GIS-based Features Inventory System (FIS), already being used to track highway features, served as the platform for this inventory. A menu-driven, searchable database was developed incorporating 13 wildlife “features” with associated attributes to categorize and describe each “asset.” This database with highway geo-referencing was downloaded onto field GPS units (Trimble® Yuma) to accomplish asset inventory and assessment of condition and maintenance needs. Asset condition (fully functional, compromised, non-functional) was tied to factors affecting functionality, and maintenance priority was assigned based on both functionality and potential impact of asset condition on motorist safety (low, high, critical). Photographs of each asset and maintenance needs were taken with the field unit. Photos were linked to asset inventory and condition files upon uploading to the FIS.

During summer 2012, ADOT inventoried all wildlife assets along 230 km (140 mi) of 10 Arizona highways, identifying a total of 1,215 assets (ADOT 2013a). These assets include:

- 11 underpasses and 3 overpasses specifically designed for wildlife passage.
- 11 large bridges, 3 traffic interchanges, and 123 suitable drainage structures (e.g., box culverts) retrofitted for wildlife passage.
- 125 km (77 mi) of wildlife (ungulate) fence and 95 km (59 mi) of reptile mesh fence.
- 123 access controls, including 85 gates, 28 cattle guards, and 10 electrified mats.
- 18 km (11 mi) of animal warning reflectors.
- 104 wildlife escape measures associated with fencing, including 53 escape ramps.

The vast majority of inventoried wildlife assets were found to be in fully functional condition with low corresponding maintenance priority. However, ADOT’s assessment did identify assets whose functionality was compromised and thus required maintenance attention. This maintenance information is now available to ADOT maintenance personnel on the FIS so that repair needs and their locations can be identified and action plans developed. Once repairs are completed, asset functionality and condition can be updated in the FIS. As new wildlife assets
are constructed, they will be inventoried and added to the FIS for periodic condition assessment along with all other features. The FIS and its wildlife inventory and condition information will prove invaluable to ADOT in developing comprehensive long-term strategies to accomplish asset maintenance in a proactive and cost-effective manner.

EMERGING ISSUES AND CHALLENGES FACING ADOT

Understanding the Magnitude of Arizona’s Wildlife Connectivity Need

The Arizona's Wildlife Linkages Assessment (Arizona Wildlife Linkages Workgroup 2006) identified approximately 1,240 km (765 mi) of Arizona highways exhibiting either issues related to highway safety associated with WVC or wildlife connectivity, or both. Highway construction activities since 2000, including that accomplished during the “big project era” along SR 260, US 93, and SR 68 account for only 75 km (46 mi), or 6%, of the total priority highway identified in the statewide assessment. Further, during this unprecedented period of construction activity on the three “big projects,” a total of 20 wildlife passage structures (3 overpasses, 17 underpasses including the 3 bridges along US 93) were constructed, yet recommendations for passage structures on future planned priority highway reconstruction based upon AGFD research (table 2) include 63 total passage structures. As such, over three times the number of passage structures remains to be built in the foreseeable future as have been funded and constructed over the past 13 years. And these priority projects that could take 25 years or longer to be completed along five highways account for 324 km (200 mi), or 26% of the total highway length identified in the statewide linkage assessment. Thus, along with completed projects, barely a third of the priority need may be addressed over a 35−40 year timeframe if we wait for all priority highways to be constructed or reconstructed.

Adapting to Declining Transportation Construction Funding

During the heyday of the “big project” era, annual budgeting for transportation facilities construction projects related to highways under ADOT’s Statewide Transportation Improvement Programs (STIP) averaged $579 million/year (2008–2013; figure 8). Owing to a variety of factors including reduced stimulus project funding as the nation recovers from the recession, coupled with reduced gas tax revenues from motorists driving more fuel-efficient vehicles, annual funding levels for highway projects under the current STIP are projected to decline and average only around $373 million/year from 2014–2018, or a 35% decline over the previous six years (figure 8; source: ADOT 2013b). This revenue decline will have a dramatic impact on ADOT’s highway construction program over the next decade or longer. ADOT’s long range transportation plan, What Moves You Arizona (ADOT 2011) places a much greater emphasis on maintaining the current transportation infrastructure (e.g., pavement preservation) than the previous long range plan; the recommended investment level tied to anticipated revenues through 2035 is just 29% of the funding level needed to satisfy all projected needs for Arizona’s transportation infrastructure. This decline in revenues coupled with the magnitude of the wildlife connectivity need underscore the growing importance of addressing wildlife connectivity across the full range of ADOT’s highway management activities as it and its partners adapt to a declining reliance on large reconstruction projects as the predominant avenue of addressing wildlife needs.
Maintaining Connectivity Momentum via Small Projects

While difficult to dispute the significance of the accomplishments made in addressing wildlife connectivity at a landscape scale as part of the projects implemented during the “big project” era, progress has also been made in the past three years as part of relatively “minor” widening projects being implemented by ADOT. Two of these widening projects have served to set the standard as to how wildlife connectivity and WVC resolution can effectively be integrated into highway widening projects, one along a rural stretch of highway (SR 86) and the other (SR 77) within a semi-urban setting north of Tucson. Widening projects have the advantage over the retrofit enhancement fencing projects previously done on SR 260 and I-17 as they include construction activities associated with drainage structure (e.g., concrete box culverts, corrugated metal pipes) extensions and various degrees of paving tied to the extent of the widening involved; the primary limitation of accommodating wildlife connectivity into such projects is typically working within existing pavement grade/elevation. Like retrofit fencing projects, a priority is to integrate existing structures (bridges, culverts) that are potentially suitable for animal passage into cost-effective connectivity strategies. Where existing structures are not suitable to accommodate wildlife passage, especially for ungulate species, the structures can be modified (e.g., adding median skylights/wells) or replaced with larger more passage-friendly structures including drop-in precast arch underpasses (figure 9) or overpasses at existing cut slope sites.
Figure 9. Various stages of construction of a drop-in precast arch wildlife underpass on I-70 in Utah, from site excavation of the east-bound lanes to setting of precast panels on the foundation walls (photos courtesy of Bruce Bonebrake), and the completed underpass and inset of a mule deer recorded in the underpass during camera monitoring a (photos courtesy of Patty Cramer).

State Route 86 Widening Project
SR 86 links Tucson to the Tohono O’odham Nation (TON). ADOT has embarked on a program of widening the existing 2-lane roadway without shoulders to improve motorist safety, adding paved shoulders and 9-m (30-ft) clear zones. The widening requires extension of existing drainage structures from 15 m (48 ft) to 27 m (88 ft), diminishing their already limited suitability for wildlife passage. One 13-km (8 mi) widening stretch was identified in the Arizona’s Wildlife Linkages Assessment (Arizona Wildlife Linkages Workgroup 2006) as one of 28 highest priority linkages statewide as it constitutes a landscape-scale corridor for far-ranging wildlife species due to its strategic location within a north-south running string of “sky islands.” Failure to capitalize upon and integrate connectivity measures into the widening project could have foregone the opportunity to address connectivity for decades. As there were no existing drainage structures suitable for passage, ADOT and the TON focused on identifying suitable sites for drop-in passage structures that could be built quickly during widening. ADOT queried its statewide crash database and found the project stretch accounted for 70% of all WVC along a 32-km (20 mi) stretch; one 3 km (2 mi) “hotspot” accounted for 56% of all WVC on the entire project. Ultimately, three passage structures and associated ungulate (and tortoise) fencing were
recommended and approved for inclusion in the widening project. The widening project is now underway and two precast arch underpasses (similar to figure 9) will be completed by spring 2014, the first on a state highway. At a later date, a wildlife overpass will be constructed as part of a separate project to address funding limitations of the Pima County Regional Transportation Authority (RTA) which is funding the wildlife elements of the project (see below).

**State Route 77 Widening Project**

The original scope of SR 77 widening project was considerably greater than the SR 86 project, with travel lanes to be added in each direction to the existing 4-lane divided highway, along with 9-m (30 ft) clear zones along the shoulders. This 10-km (6 mi) stretch also falls within a priority wildlife linkage identified in *Arizona’s Wildlife Linkages Assessment* (Arizona Wildlife Linkages Workgroup 2006). This priority reflects the fact that the project likely represents the last opportunity to accommodate wildlife connectivity needs across SR 77 due to the rapidly diminishing open space corridors due to human development in this semi-urban setting. In 2009, a proposal was developed and approved by the RTA to construct two drop-in precast arch underpasses (less than 0.5 km apart) and a large wildlife overpass (figure 10), all linked by ungulate fencing. Over the course of the next two years, a wildlife connectivity technical advisory committee (TAC) guided development of refined connectivity strategies during the design phase. Initially, the TAC recommended relocating one of the underpasses to achieve enhanced spacing of passages, though ungulate fencing at the new site adjacent to a planned commercial development proved controversial. Ultimately, the TAC eliminated the second underpass altogether but greatly expanded the scope of the overall connectivity project to incorporate three large existing bridges into the landscape-scale strategy utilizing ungulate fencing to link the new and existing structures. Though changes to the original project occurred as a result of political realities of working in a semi-urban setting, the project evolved into a more comprehensive connectivity strategy that was subsequently supported by the RTA with additional funding. Construction activities on this project will begin in late-2013.

*Figure 10. Rendering of the State Route 77 wildlife overpass north of Tucson, part of a comprehensive wildlife connectivity strategy also involving a new wildlife underpass and three existing large bridges linked with wildlife (ungulate) fencing.*
The Pima County RTA – a Model for Sustainable Wildlife Connectivity Funding

In 2006, Pima County voters approved the Pima County RTA’s $2.1 billion, 20-year regional transportation plan and a half-cent sales tax to fund the plan. The RTA plan includes roadway, safety, transit, and environmental and economic vitality projects and is now in its 7th year of implementation. The RTA plan committed $45 million to wildlife connectivity activities including construction, design, and monitoring and research over its 20-year life. The two largest commitments for funding have been for the SR 77 widening project wildlife connectivity elements, totaling over $13 million, and the SR 86 widening project wildlife elements totaling nearly $4 million to date, both being pursued in cooperation with ADOT on state highways. With ADOT’s construction funding in decline, the availability of RTA funds to address wildlife connectivity needs in Pima County has proven invaluable; similar funding does not exist elsewhere in Arizona, including Maricopa County with its own transportation funding program. Additional benefits of the RTA have included its local-level and timely responsiveness to funding projects of opportunity, such as the SR 86 widening project. Further, its ability to integrate project elements beyond the ADOT ROW into a single funding package as done for the SR 77 project was important. As ADOT construction funding is anticipated to decline even further (ADOT 2011), the Pima County RTA constitutes a sustainable funding model including wildlife connectivity that serves as a proactive funding model for other jurisdictions.

BIOGRAPHICAL SKETCH (Lead Author)

Norris Dodd, Wildlife Connectivity Program Coordinator, Environmental Services, Arizona Department of Transportation, just recently filled a new Wildlife Connectivity Program Coordinator position with Arizona Department of Transportation’s Environmental Services, where he will be coordinating statewide connectivity planning and integration into ADOT projects. Prior to that, Norris was employed by AZTEC Engineering as a senior natural resource specialist where he focused on planning and implementation of innovative strategies to resolve wildlife-highway conflicts with ADOT and other partners. He retired from the Arizona Game and Fish Department in 2008 after 29 years; as a wildlife research biologist his last 10 years with the Department, his research focused on wildlife relationships to highways across northern Arizona and helped raise recognition of the ability to meet both transportation and ecological objectives with highway construction. He received B.S. and M.S. degrees from Arizona State University, and is a past president of The Wildlife Society Arizona Chapter. He lives in Pinetop with his wife, Rebecca, with whom he as 2 daughters.

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