Strategies to Reduce Burro-Vehicle Collisions in the Lake Pleasant Area

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16. Abstract

Burro-vehicle collisions (BVCs) have the potential to cause motorist fatalities, injuries, and property damage. The Lake Pleasant area north of Phoenix, Arizona, has reported high BVC rates on highways within and around the Lake Pleasant Herd Management Area (LPHMA). Although interactions between wildlife and highways and specifications for wildlife-vehicle collision mitigations are increasingly well documented in Arizona and elsewhere, there remains a dearth of information relating to equids (horses and relatives), and information that does exist focuses primarily on horses (*Equus caballus*), not on burros (*E. asinus*). To address safety concerns and reduce BVCs in Arizona in general and the Lake Pleasant area in particular, Arizona Department of Transportation initiated a study to inform the development of mitigation strategies by determining the factors causing BVCs. This study analyzed burro-highway interactions using data from the BVC records collected within the study area, still cameras placed along right of way fences, and GPS movement data from burros. Using these data, the research team developed a set of design recommendations and best practices to reduce BVCs in the Lake Pleasant area and throughout Arizona.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ACRONYMS AND ABBREVIATIONS

ADOT	Arizona Department of Transportation
AGFD	Arizona Game and Fish Department
AML	appropriate management level
BLM	US Bureau of Land Management
BuRRITo	Burro Roadway Reporting Interagency Tool
BVC	burro-vehicle collision
CI	confidence interval
FIS	Features Inventory System
GIS	geographic information system
HMA	herd management area
IABT	interagency burro team
LPHMA	Lake Pleasant Herd Management Area
MP	milepost
NEPA	National Environmental Policy Act
OHV	off-highway vehicle
RABID	Rapid Analysis of Batched Image Data application
ROW	right of way
USGS	US Geological Survey
UTM	Universal Transverse Mercator

LIST OF SPECIES

Animals	**Scientific Name**
burro	*Equus asinus*
horse	*Equus caballus*

EXECUTIVE SUMMARY

Burro-vehicle collisions (BVCs), collisions between a burro and a vehicle or vehicle collisions caused by the presence of a burro, have the potential to cause motorist fatalities, injuries, and property damage. The Lake Pleasant area north of Phoenix, Arizona, has a recent history of high BVC rates on highways within and around the Lake Pleasant Herd Management Area (LPHMA). Although wildlife interactions with highways and specifications for wildlife-vehicle collision mitigations are increasingly well documented in Arizona and elsewhere, information relating to equids (horses and relatives) is limited and focuses primarily on horses (*Equus caballus*) rather than burros (*E. asinus*).

To address safety concerns and reduce BVCs in Arizona in general and the Lake Pleasant area in particular, the Arizona Department of Transportation (ADOT) initiated this study to determine the factors that contribute to BVCs and develop mitigations to reduce BVCs. This study analyzed burro-highway interactions through BVC records collected by partner agencies within the study area, images from still cameras placed along right of way (ROW) fences, and movement data collected from GPS collars fitted on burros.

The primary factors found to contribute to BVCs within the Lake Pleasant study area were:

- Seasonality, with BVC peaks from October through January and troughs from June through August
- At-grade highway crossings where burros completed highway crossings within the paved ROW
- Access points through ROW fence where burros entered ROW via unfenced sections of highway, gaps in ROW fence, raised bottom wires exceeding 18 inches, unguarded driveways and intersections, sedimented crossing guards, gates with apertures greater than 18 inches, and open gates

Design recommendations and best practices are described in detail to reduce BVCs in the Lake Pleasant area and throughout Arizona where burros are in close proximity to highways. Below are highlights of key recommendations:

- Install ADOT barbed wire game fence in all BVC-related areas.
- Maintain bottom wire heights at 18 inches above ground level throughout the fenced area.
- Avoid gaps exceeding 6 inches between fence terminuses and structures.
- Prevent below wire crossing opportunities where fences traverse dramatic topographical changes.
- Adopt flood gate designs where ROW fences cross washes to minimize the extent of damage from fence blowouts.

- Develop updated fence details to incorporate cut-prevention measures where trespassing is a recurring issue.
- Schedule fence surveys shortly before annual peaks in BVCs (late September or early October for the Lake Pleasant area).
- Install crossing guards at unguarded driveways associated with BVCs.
- Install and tie in wing fence within crossing guard vaults to prevent burros from making cross-jumps or traversing vault ledges.
- Adopt ADOT type 1 single or double gate designs for gate installations in burro habitat. ADOT type 2 ranch-style gates already in place remain effective at low-traffic driveways. Block any apertures within gates that are greater than 18 inches.
- Support the Burro Roadway Reporting Interagency Tool (BuRRITo) app as the standard burro-ROW incident reporting tool, and develop live dashboards to facilitate mitigation response.
- Improve and extend ROW fence to restrict burro movements from within herd management areas (HMAs) onto surrounding lands.
- Advocate for the US Bureau of Land Management to remove nuisance burros from lands outside of HMAs.
- Consult with wildlife agency professionals when developing BVC mitigations and during implementation.

CHAPTER 1. INTRODUCTION

BACKGROUND

Burros (*Equus asinus*) were introduced in North America by Spanish explorers in the 16th century (Figure 1). Also referred to as donkeys or asses, burros were used primarily as a pack animal until the early 1900s when mining activities waned and roads became more commonplace (Ruffner and Carothers 1982). Many of these burros were released into the wild, primarily in the deserts of the western United States, which is somewhat similar to burros' native habitat in northeastern Africa (McKnight 1958). These animals then began to form populations that have flourished over time. In fact, overpopulation has been a concern for more than 50 years (McKnight 1958; Cook 1975).

Figure 1. Burros Near the Lake Pleasant Herd Management Area

At the same time, the feral horse (*E. caballus*) population was also increasing in the United States. Interest in the well-being of wild horses and burros led the US Congress to pass the Wild Free-Roaming Horses and Burros Act in 1971 to manage, protect, and control wild horses and burros on public lands (Cook 1975).

The Wild Free-Roaming Horse and Burro Act of 1971 directs the US Bureau of Land Management (BLM) to manage wild burros in balance with wildlife and habitat conservation efforts (BLM 2010). To find this balance, BLM designated herd management areas (HMAs) where horses and burros are protected and intended to be kept at appropriate management levels (AMLs). As populations increased, the need to maintain herds at AMLs also increased. However, Congress mandated that wild, free-roaming horses and burros be protected from capture, branding, harassment, or death. Under this mandate, current population management options are limited to captures (or gathers) where, once captured, horses and burros are held in a BLM adoption facility until adoption. But adoption rates cannot keep pace with population growth, and adoption facilities have reached maximum capacity. Additionally, holding horses and burros for adoption is expensive and taxing on federal financial resources. For example, in fiscal year 2017, the BLM spent nearly 60 percent of its $81 million budget on the care of gathered animals. The lifetime cost to BLM for one horse that remains unadopted is $48,000. In 2018, 46,000 unadopted animals were in holding; total husbandry costs will top $1 billion over the animals' lifetimes (BLM 2018b). The limited capacity of BLM adoption facilities and limited funding to hold horses and burros keep them in the wild where populations continue to increase. Research shows that a single wild horse herd can increase 15 percent to 20 percent annually and can double in size in four to five years. In 2018, AMLs for both horses and burros in the western US was 26,715 animals. The estimated population was 86,000, more than three times the AML (BLM 2018b).

Initially, one of the biggest concerns of horse and burro overpopulation was the impact on wildlife habitat. Studies to document habitat degradation and ecosystem integrity have been ongoing for decades (Hanley and Ward 1977; Seegmiller and Ohmart 1981; Krausman et al. 1989; Marshal et al. 2012). More recently, however, as horse and burro populations expand outside of the HMAs, concerns for the impacts on humans have come to the forefront, particularly horse- and burro-vehicle collisions (BVCs), which can cause human injury and can potentially be fatal (Figures 2 and 3). The overpopulation of both horses and burros is causing a motorist safety concern in Arizona as horses and burros encroach on roadways.

Arizona is an open range state, meaning that it is the responsibility of the landowner (or in this case, road owner) to fence out livestock. In herd districts, livestock owners are responsible for fencing in their livestock. This antiquated law is under debate and has recently put more liability on the livestock owner, requiring that the owner fence in its livestock in incorporated areas. As standard practice, Arizona Department of Transportation (ADOT) fences most of its rights of way (ROWs). Occasionally, when livestock is not present and stakeholders provide a good case for not fencing, ADOT will omit fencing along ADOT roads.

Even with ROW fencing, vehicular collisions with horses and burros can still occur. For example, the burro population in the greater north Phoenix area near Lake Pleasant Herd Management Area (LPHMA) is growing and appears to be expanding its range rapidly. While the BLM's burro removal efforts in this area are ongoing, burro population growth has outpaced existing resources. BVCs in LPHMA between May 2013 and April 2016 resulted in 48 burros killed on state highways and 58 on nonstate highways.

Outside of the LPHMA, burro populations are largely uncontrolled and are leading to an increase in BVCs. So far, these collisions have resulted mostly in property damage and minor injury, but there is the

Figure 2. Vehicle Damage Caused by a BVC

Figure 3. ADOT Responding to a Report of a BVC

potential for serious injuries or fatalities, especially for motorists driving small cars or riding motorcycles (Figures 2 and 3).

In 2013, an interagency burro team (IABT) was formed to evaluate current conditions and options to reduce BVCs in the Lake Pleasant area. This IABT consisted of representatives from ADOT, Arizona Game and Fish Department (AGFD), BLM, Department of Public Safety, Arizona State Land Department, Maricopa County, and the Cities of Phoenix and Peoria. IABT members began evaluating available options, implementing short-term solutions, and discussing the need for long-term solutions, which prompted this research study to provide a data-driven approach to long-term BVC mitigation.

IMPACTS OF ROADS ON BURROS: CURRENT STATE OF PRACTICE AND REVIEW OF THE LITERATURE

Because burro populations have only recently expanded to areas outside of the HMAs, the literature on burro interactions with roads is limited. Documentation of vehicle collisions with feral horses is more common since the range of these horses encompasses that of burros, and their larger body size poses a higher risk of injury or death to motorists (Langley et al. 2006).

Nevada, another open range state, has also seen a recent increase in horse and burro populations and in collisions with these animals. In 2018, Nevada DOT released a report that prioritized animal-vehicle collision hot spots for future mitigation efforts (Cramer and McGinty 2018). Nevada documented 348 horse-vehicle collisions from 2006 to 2018 (34.8 per year), the third highest of all animal-vehicle collisions (mule deer and cattle were numbers 1 and 2, respectively). Horse-vehicle collisions were responsible for more motorist fatalities than other animals evaluated (Cramer and McGinty 2018). Horses were mentioned in seven of top 25 animal-vehicle collision hot spots (28 percent).

Well-designed and maintained fences appear to hold the most promise for keeping horses and burros off roadways. In the early part of this decade, ADOT constructed a wildlife-friendly ROW fence along U.S. Route 95 near Lake Havasu City after a rash of BVCs. Today, BVCs occur in this area only occasionally. Similarly, Nevada constructed fencing to keep horses off the road along three stretches of highway. Results from these efforts are pending but show early promise (Cramer and McGinty 2018).

Because horses and burros are similar to elk and deer in body size and, though to a lesser extent, leaping ability, the methods used to reduce wildlife-vehicle collisions and maintain habitat connectivity for large ungulates (such as 8-foot fencing along with overpasses and underpasses) could deter horses and burros. Researchers studying the effectiveness of the U.S. Route 68 bighorn sheep crossings in Arizona documented more use by burros than by bighorn sheep (Bristow and Crabb 2008). In Nevada, horse-specific crossings linked with wildlife-friendly ROW fencing along two roads have documented horse use (Figure 4) (Cramer and McGinty 2018). Although wildlife crossings, which connect habitat, could benefit horses and burros, they may not always be desirable, particularly when limiting range expansion is a goal. It is also important to allow wildlife to move throughout their range, reducing the potential for habitat fragmentation and genetic isolation.

Source: Nevada DOT

Figure 4. Horses Using a Wildlife Crossing In Nevada

PROJECT NEED AND OBJECTIVES

In 2015, 40 burros were killed by vehicles in the Lake Pleasant area, the highest annual total in this area to date. While it is known that the burro population increased in this area, how burros access the fenced ROWs is not known. Additionally, little is known about how burros move and behave near roadways and about barriers (such as fencing) and other measures that are most effective at excluding them from the ROW. The increasing number of BVCs warrants the need to understand burro behavior and their access to roadways to determine effective and focused preventive measures that mitigate burro roadway access and reduce BVCs, specifically in the Lake Pleasant area.

The objective of this study is to better understand burro movements in relation to roads by evaluating BVC crash data, inventorying existing ROW barriers, monitoring burro movements near roadways, and collecting and analyzing data regarding the effectiveness of barriers to minimize burro access to the road. Information gathered from this study is intended to be used to help formulate recommendations that may be used to reduce BVCs locally and statewide while maintaining habitat connectivity for native wildlife species.

CHAPTER 2. BVC STUDY AREA SELECTION AND BASELINE DATA ANALYSIS

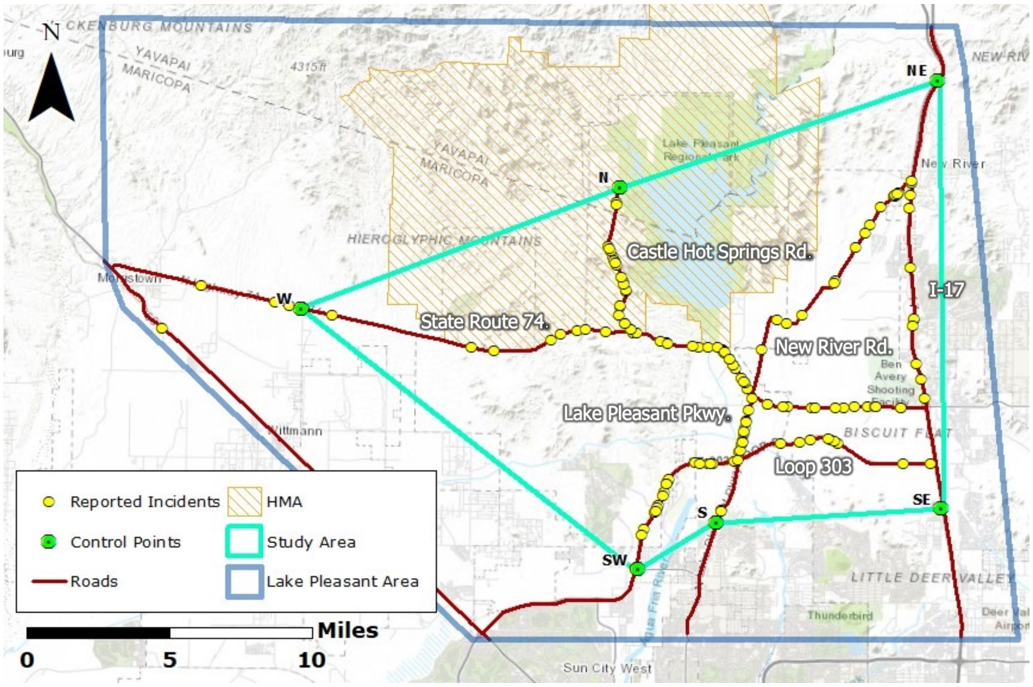
STUDY AREA

The Lake Pleasant area incorporates portions of Maricopa and Yavapai counties in central Arizona and primarily consists of Upland Sonoran Desert scrub. It includes the 103,000-acre LPHMA, stretching from Lake Pleasant in the east to the Hieroglyphic Mountains in the west. The LPHMA was established to protect a herd of free-roaming burros at a designated AML of 166 to 208. BLM, US Geological Survey (USGS), and AGFD surveys conducted in 2017 estimated 517 burros in the Lake Pleasant area, 249 percent above the upper limit of the AML range (BLM 2018a).

The initial area for evaluation is located on the northwest edge of the Phoenix metropolitan area and encompasses several ADOT highways: Interstate 17 (I-17), State Route 74 (SR 74), U.S. Route 60 (U.S. 60), and State Loop 303 (Loop 303). Several major arterial streets under the jurisdiction of local authorities are also in this area: Lake Pleasant Parkway and Castle Hot Springs Road (City of Peoria), and New River Road (City of Phoenix).

The research team narrowed the study area to locations where a majority (97.4 percent, or 147 of 151) of BVCs occurred from May 1, 2013, to December 31, 2016 (Figure 5). The boundaries generally coincide with an intersection or milepost (MP). Table 1 provides the coordinates from the Universal Transverse Mercator (UTM) coordinate system of the control points according to a projection in UTM Zone 12N of the North American Datum of 1983.

The study area included 72.7 miles of ROW from six highways under three jurisdictions: I-17 from the Central Arizona Project alignment in the south to the Table Mesa Road exit at MP 235.7 in the north; Loop 303 from the Lone Mountain Parkway exit east to the I-17 interchange; SR 74 from the I-17 junction west to the intersection with N 211 Avenue at MP 7; New River Road from the SR 74 intersection north to the I-17 intersection; the paved extent of Castle Hot Springs Road from the SR 74 intersection north to Castle Creek Drive; and Lake Pleasant Parkway from the SR 74 intersection south to the intersection with Westwing Parkway.



Source of map imagery: Esri

Figure 5. Location of the LPHMA and Study Area

Table 1. Control Points of the Study Area

ID	Highway	UTM_E	UTM_N
W	SR 74	359643	3745937
N	Castle Hot Springs Road	377652	3752789
NE	I-17	395553	3758831
SE	I-17	395791	3734624
S	Lake Pleasant Parkway	383097	3733870
SW	Loop 303	378615	3733120

BASELINE DATA ANALYSIS

Comprehensive BVC and burro-ROW incident data in the Lake Pleasant area are available from May 2013 to December 2019. A burro-ROW incident refers to a report filed by ADOT, the Department of Public Services, BLM, or AGFD personnel about a burro encroachment onto an ROW. The research team compiled BVC and burro-ROW incident data from ADOT, BLM, and AGFD into a single, standardized database for use in the project. Historic BVCs and burro-ROW incidents within the study area from January 1, 2014, through December 31, 2016, were analyzed to provide baseline data for the study.

The final analytic data set consisted of 134 unique records, 115 of which were spatially referenced. Thus, all spatial analyses conducted in this section use 115 records, while the seasonal, annual, and jurisdictional trend analyses use all 134 records. Researchers flagged each record that resulted in at least one collision either with at least one burro or with another vehicle due to a burro within the ROW, resulting in 92 flagged records in the database. These records are hereafter referred to as "incidents resulting in BVCs," and they differ from BVCs in that a single burro-ROW incident may result in multiple BVCs.

Note: The trend analysis presented in this chapter was limited by differences in agency reporting of some data such as time-sensitive variables, number of individual burros involved, and age or sex of the burro.

Trends by Year

From 2014 through 2016, the greatest number of burro-ROW incidents was reported in 2015, which was 43 percent and 133 percent higher than 2014 and 2016, respectively. The differences between 2014 and 2015 may be related to increasing burro populations resulting in an increase in burro-ROW incidents. The drop in 2016 may be due to active burro management activities in the area (Figure 6), which included cleaning out crossing guards, fixing downed ROW fence, installing new fence, and removing burros.

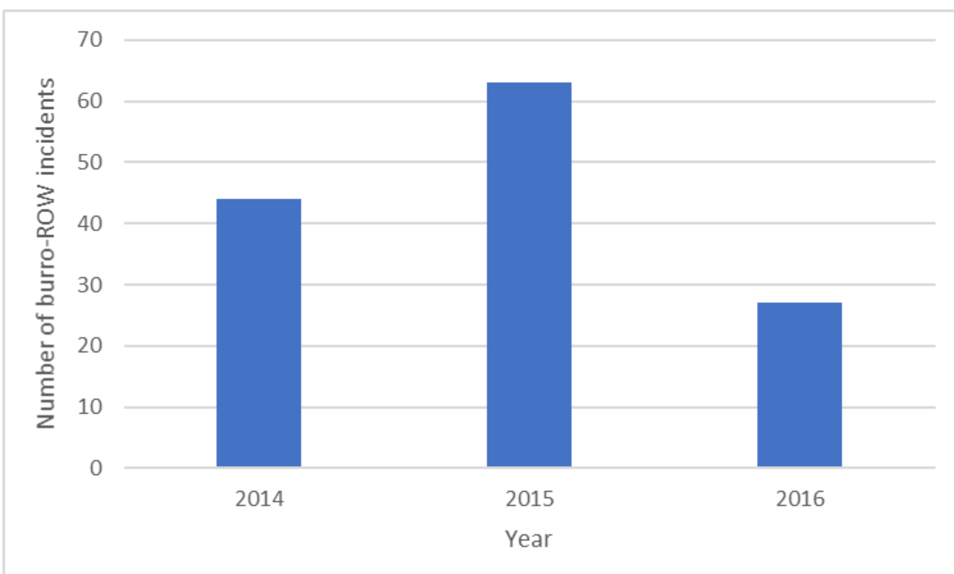


Figure 6. Total Burro-ROW Incidents by Year (2014–2016)

When evaluated by highway during this period, burro-ROW incidents were highest on SR 74, particularly in 2015, followed by Castle Hot Springs Road. For all highways except Loop 303, 2015 showed the highest number of burro-ROW incidents (Figure 7). (Burro-ROW incidents on Loop 303 remained consistent across the three years.)

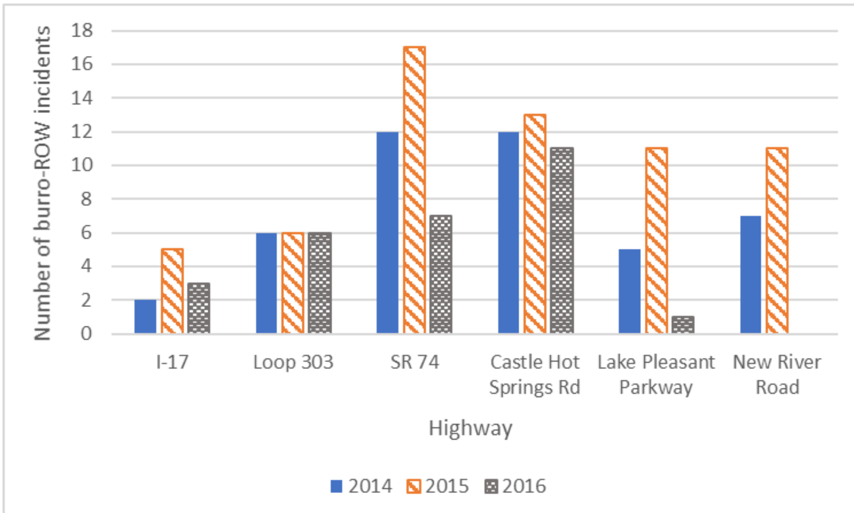


Figure 7. Total Burro-ROW Incidents by Highway and Year

Trends by Highway and Jurisdiction

Burro-ROW incident data from 2014 through 2016 is summarized both by highway (Table 2) and by jurisdiction (Table 3). Data include the numbers of burro-ROW incidents, number and percentage of incidents resulting in BVCs, and miles assessed. These values were used to calculate the incidents per mile displayed in Figures 8 through 11.

Table 2. Burro-ROW Incident Data by Roadway (2014–2016)

Highway	Burro-ROW Incidents	Incidents Resulting in BVCs	% Incidents Resulting in BVCs	Extent (mi)
I-17	9	3	33%	15.31
Loop 303	18	10	56%	13.42
SR 74	36	25	69%	23.36
Castle Hot Springs Road	36	34	94%	5.55
Lake Pleasant Parkway	17	13	76%	4.72
New River Road	18	7	39%	10.32

Highway	Burro-ROW Incidents	Incidents Resulting in BVCs	% Incidents Resulting in BVCs	Extent (mi)
Total	**134**	**92**	**69%**	**72.68**

Table 3. Burro-ROW Incident Data by Jurisdiction (2014–2016)

Jurisdiction	Burro-ROW Incidents	Incidents Resulting in BVCs	% Incidents Resulting in BVCs	Extent (mi)
ADOT	63	38	60%	52.09
City of Peoria	53	47	89%	10.27
City of Phoenix	18	7	39%	10.32
Total	**134**	**92**	**69%**	**72.68**

Of the six highways evaluated, the highest reported percentage of incidents resulting in BVCs occurred on Castle Hot Springs Road (Figure 8). The number of burro-ROW incidents per mile is double that of Lake Pleasant Parkway, the next most problematic highway assessed. Note the high conversion rate of burro-ROW incidents to BVCs for these two highways, which are over 70 percent, as well as for SR 74 at 69 percent (Figure 8). Based on the data, I-17 had the fewest incidents resulting in collisions (Table 2), possibly because some segments of the highway within the study area fall beyond the core range of burros.

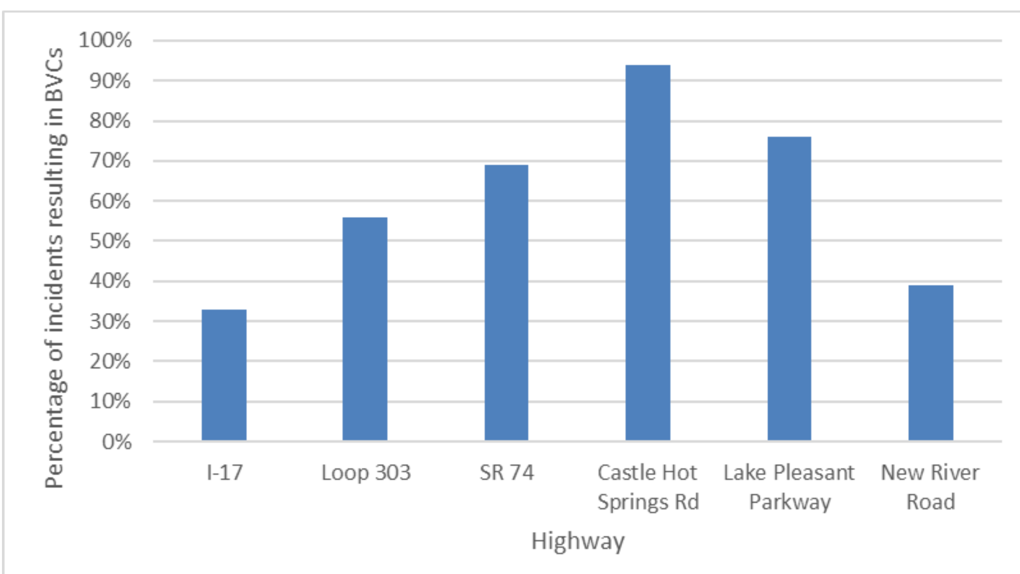


Figure 8. Percentage of Incidents Resulting in BVCs by Highway (2014–2016)

Highways under the City of Peoria's jurisdiction had more than three times the total number of incidents per mile than ADOT and the City of Phoenix. This pattern is also shown in the reported collision incidents per mile (Figures 9 through 11). The City of Peoria's high number of BVCs occurred within an area with extensive unfenced sections of ROW.

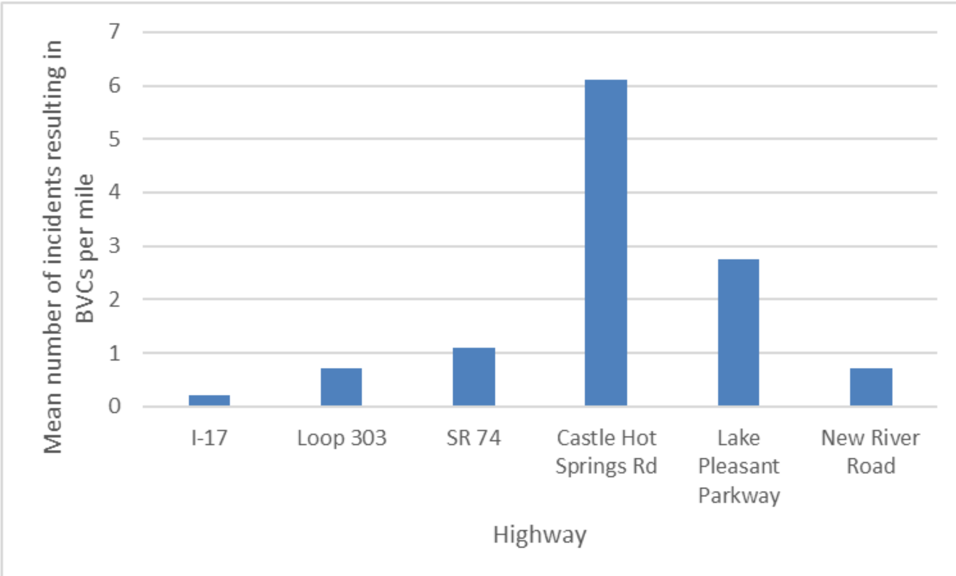


Figure 9. Average Number of Incidents Resulting in BVCs Per Mile by Highway (2014–2016)

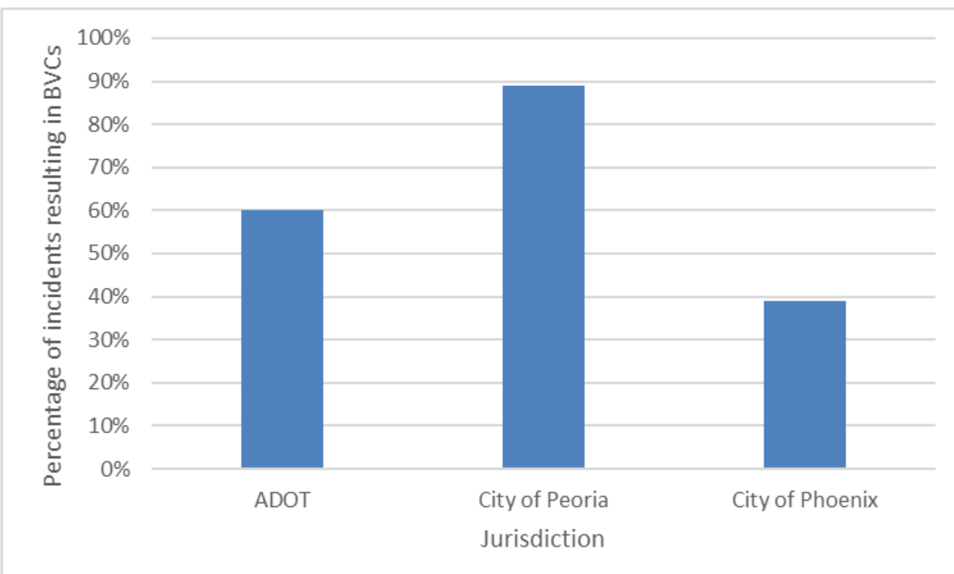


Figure 10. Percentage of Incidents Resulting in BVCs by Jurisdiction (2014–2016)

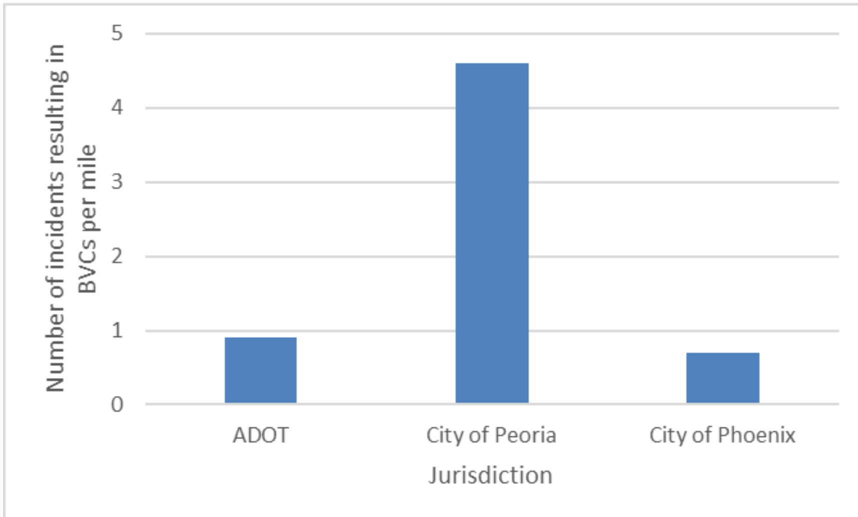


Figure 11. Incidents Resulting in BVCs Per Mile by Jurisdiction (2014–2016)

Seasonal Trends

Figures 12 and 13 illustrate seasonal trends assessed by month from 2014 through 2016. Burro-ROW incident rates are lowest in early summer (June and July). Rates are generally highest from late fall through early spring (October to March) with a peak in January. There is a noticeable decline in burro-ROW incident rates in November versus October and December. These patterns are consistent across all three years (Figures 12 and 13). The number of incidents that resulted in BVCs was highest in October, December, and January. These trends may be explained by burro behaviors driven by hormonal or environmental factors such as peaks in mating season, water requirements, and vegetation growth, but could also include fluctuations in traffic volumes.

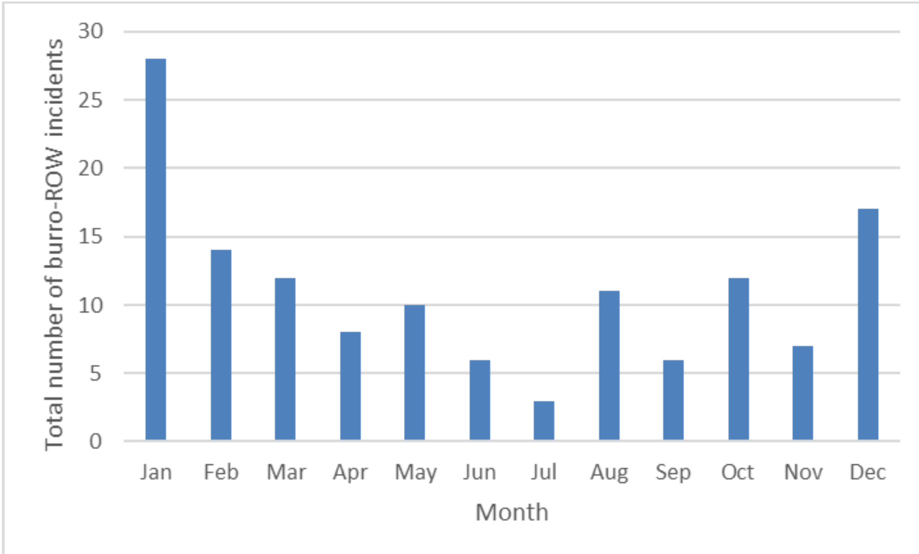


Figure 12. Total Number of Burro-ROW Incidents by Month (2014–2016)

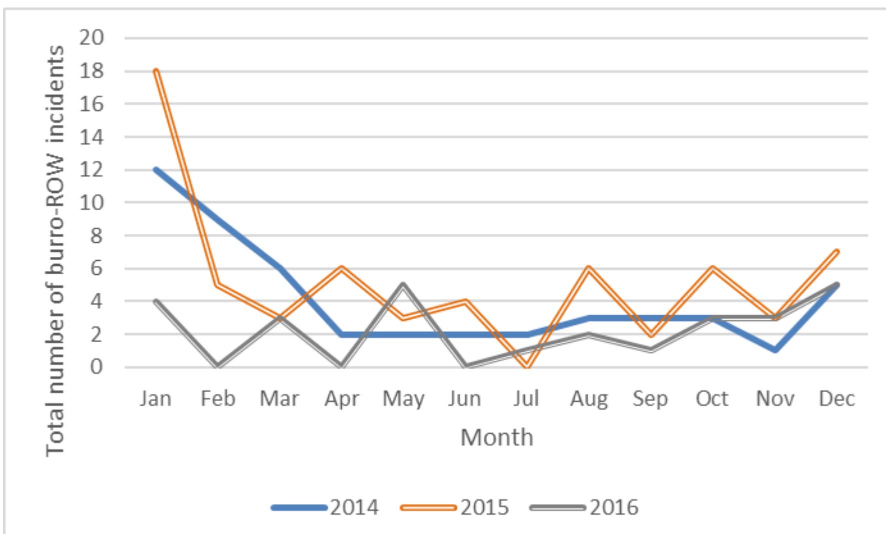


Figure 13. Total Number of Burro-ROW Incidents by Month and Year

Weekly Trends

Figure 14 depicts burro-ROW incident rates by day of the week. Weekdays (Monday to Friday) are generally more problematic than weekends (Saturday and Sunday), which is reflective of differences in traffic volume during these days. Highways in the City of Peoria had a noticeable peak in burro-ROW incidents on Sundays and trough on Thursdays, which was not reflected in other jurisdictions. The City of

Phoenix highways displayed consistently low burro-ROW incident rates across all days of the week. These individual jurisdiction trends could be driven by fluctuations in traffic volumes and are further explored later in this report.

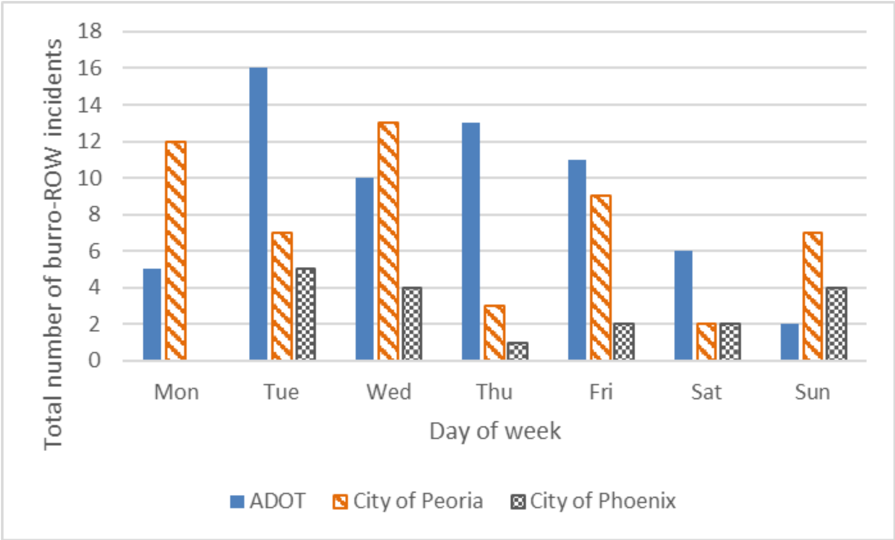
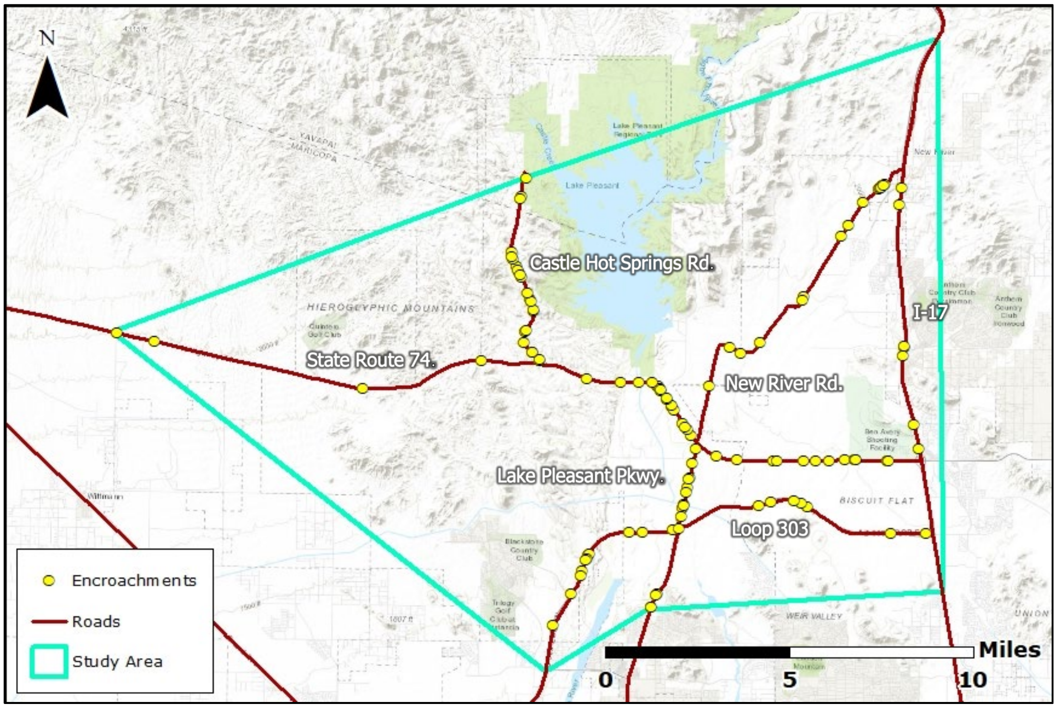


Figure 14. Total Burro-ROW Incidents by Day of the Week and Jurisdiction (2014–2016)

Hot Spot Analysis

Researchers used the Optimized Hot Spot Analysis tool to evaluate the spatial analytic data set (Figure 15); data were reviewed in 0.1-mile segments. The tool uses the Getis-Ord Gi* statistic to identify statistically significant spatial clustering of records in an ArcGIS desktop environment. Hot spot analyses produce a heat map of significance values at three confidence intervals (CIs): 90 percent, 95 percent, and 99 percent. These identify areas of high or low burro-ROW incident concentrations relative to the full input data set and analysis area, and are referred to as hot spots and cold spots, respectively. In this context, these outputs highlight particularly problematic or unproblematic sections of the highway based on the input data.

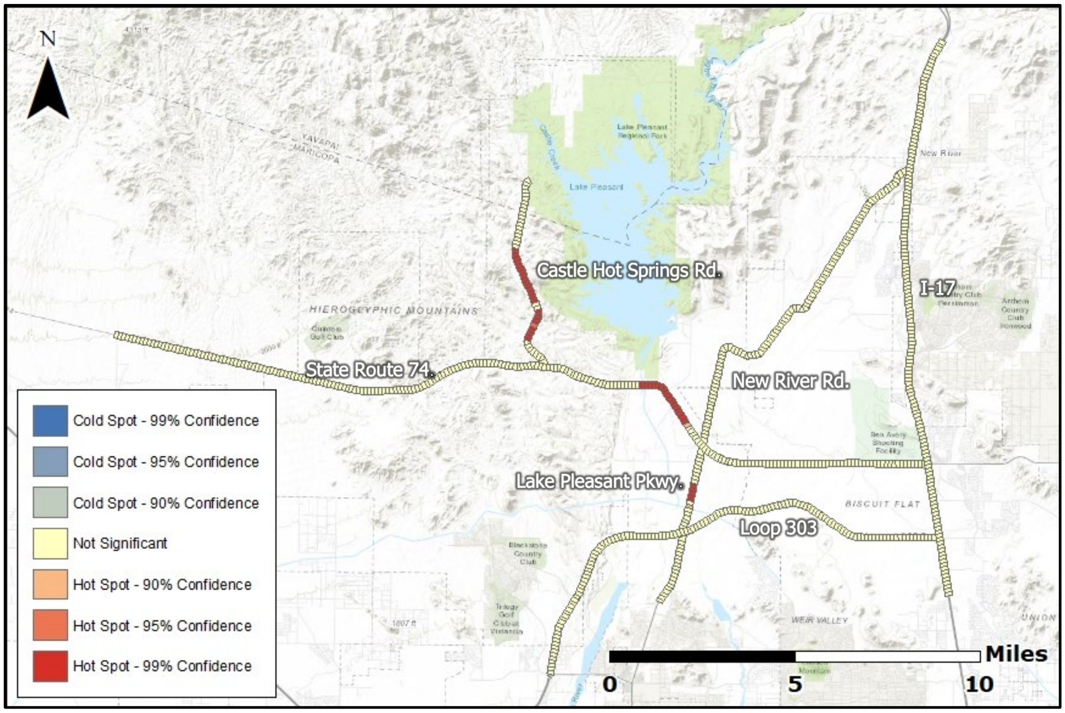


Source of map imagery: Esri

Figure 15. Distribution of Burro-ROW Incidents Across the Full Study Area

Separate hot spot outputs were produced from two inputs: total burro-ROW incidents for the full study area and all burro-ROW incidents for ADOT highways only. The resulting hot spot outputs are shown in Figures 16 and 17, respectively. Each hot spot output was analyzed in conjunction with the fence inventory to identify problematic areas and potential solutions as well as to evaluate factors associated with areas of high incidence of burro-ROW incidents. Individual highways within the study area were not analyzed because of the small sample size (less than the required minimum of 30).

No hot spots were detected along New River Road or I-17 under the input combinations explored. Hot spots were also not detected on Loop 303 when analyzing data across the full study area versus individual jurisdictions, which would highlight areas important for each jurisdiction. The southern two-thirds of Castle Hot Springs Road (south of the Scorpion Bay Access Road) and the section of SR 74 between MP 21 and MP 23 account for broad and highly significant hot spots. Equally, a more confined but significant hot spot was identified on Lake Pleasant Parkway along an unfenced stretch immediately north of the Central Arizona Project alignment (Figure 16).

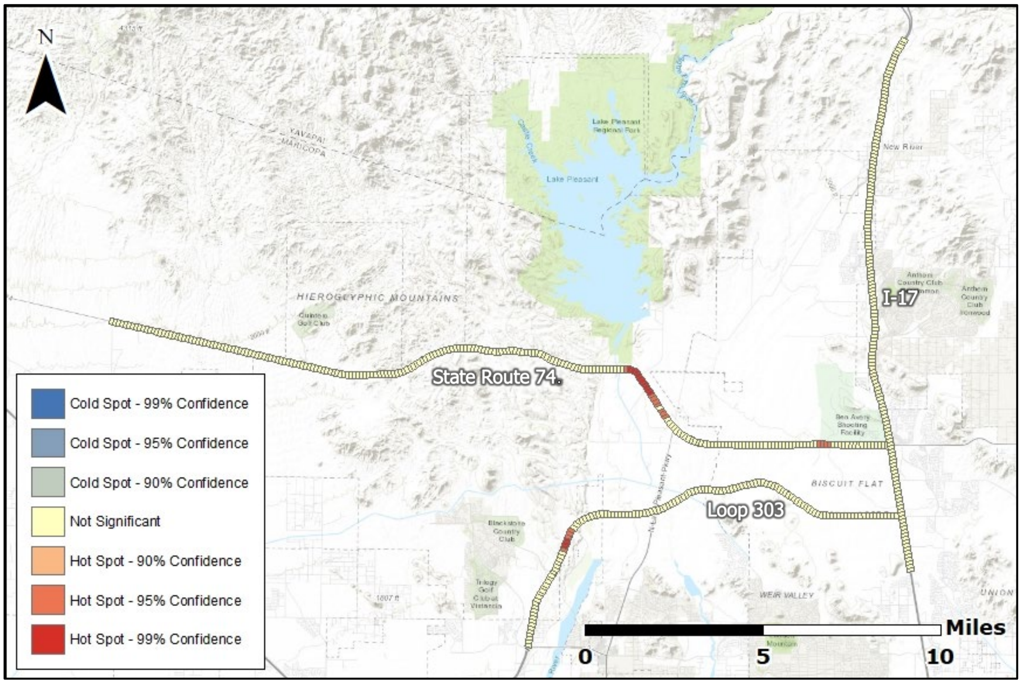


Source of map imagery: Esri

Figure 16. Hot Spot Analysis Output for Burro-ROW Incidents in the Study Area

Three burro-ROW incident hot spots were present on ADOT highways only (Figure 17):

- SR 74 near MP 29, closely associated with the western entry to AGFD's Ben Avery Shooting Facility (a compact hot spot)
- Loop 303 near the Lone Mountain Parkway exit
- Area between MP 21 and MP 23 along SR 74, which becomes less significant at its southern extreme



Source of map imagery: Esri

Figure 17. Hot Spot Analysis Output for Burro-ROW Incidents on ADOT Highways

CHAPTER 3. METHODS

To describe the factors influencing BVC patterns, the research team used three primary data types:

- BVC records gathered from the Burro Roadway Reporting Interagency Tool (BuRRITo), the interagency application developed to report burro incidents (Appendix A), and from databases maintained by ADOT, BLM, and AGFD
- Still cameras oriented to capture burro approaches to potential ROW access points
- Spatial data consisting of feature attributes of ROW fence and structures collected using the ArcGIS Survey123 and ADOT Feature Inventory System (FIS), movement data collected from GPS tracking collars outfitted on female burros (jennies), and existing reference layers

BVC records were used to assess reductions in BVCs before and throughout the research project, identify collision hot spots and priority areas for mitigation, and assess the influence of ROW fence features on collision rates. Throughout the project, the research team also responded to new BVCs to document location characteristics and ROW access points and to suggest mitigation measures. Still-camera images were collected to determine if burros utilized potential ROW access points or crossing structures and to identify particularly high-risk feature types. Survey123 data were used in combination with still-camera data to determine access point and crossing structure characteristics that may influence burro use. GPS movement data were used to identify areas where burros regularly approach the ROW and patterns of those approaches. FIS and spatial reference data supported the evaluation of ROW fence and environmental influences on BVCs and burro movements.

BVC DATA: DOCUMENTATION, COLLATION, AND ANALYTICAL METHODS

Burro-ROW incident data from the ADOT, BLM, and AGFD databases were collated and standardized to produce an analytical data set for use in this study. The research team also developed BuRRITo within the Esri Survey123 mobile application to document burro-ROW incidents beginning in November 2017. The app provides a centralized, spatially accurate, and consistent interagency data collection platform.

The research team compiled BVCs by road, jurisdiction, month, season, and year from January 1, 2014, to December 31, 2019. This represented the full collision data set used in the analysis.

To assess the overall effectiveness of the BVC mitigation efforts on ADOT roads within the study area, the research team calculated BVCs per mile across different roadways. Average BVC rates were calculated for a baseline (from 2014 to 2016) and from 2017 to 2019. Data were analyzed to compare changes in the BVCs per mile before and after mitigation options were implemented.

Researchers used hot spot analyses to identify highway sections within the study area with significantly high clustering of BVCs. Then BLM and ADOT environmental and maintenance staff prioritized implementation of mitigation efforts. The research team then conducted pre- and postmitigation analyses by road, jurisdiction, month, season, and year where sample sizes were adequate (greater than

30 collisions). The analysis identified spatial and temporal hot spot patterns where further mitigation recommendations were needed.

To evaluate the factors that contributed to BVCs, the research team conducted a logistic regression analysis to determine what factors increase the odds of a BVC. Variables were derived from fence inventory data, existing spatial data sets, and remote sensing layers to assess the relationship between incident patterns and environmental and road-related characteristics.

STILL CAMERA DATA: PLACEMENT, REVIEW, AND ANALYTICAL METHODS

The research team first gathered information about ROW features such as the presence of crossing guards; unguarded driveways (where an access road crosses the ROW fence without a guard); barrier arm gates (Figure 18); fence gaps (Figure 19); raised bottom wires (Figure 20); low top wires (Figure 21); between-wire gaps (Figure 22); Jersey barrier tie-ins (Figure 23); and below-grade crossings from different sources that include fence inventory, burro movement data, collision hot spots, and ongoing BVC site investigations. Features in core burro habitat with indications of regular burro presence (such as hoofprints or scat) were selected as priority sites where cameras were deployed for varying periods of time between 2017 and 2020. The period of deployment depended on available resources, alterations or removal of the monitored feature, evolving monitoring priorities, and vandalism.

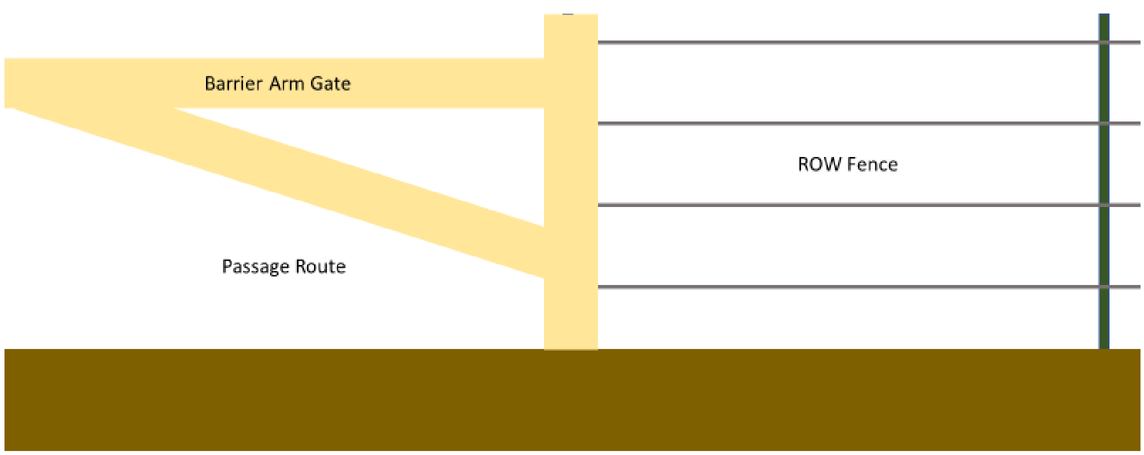


Figure 18. Diagram of a Barrier Arm Gate

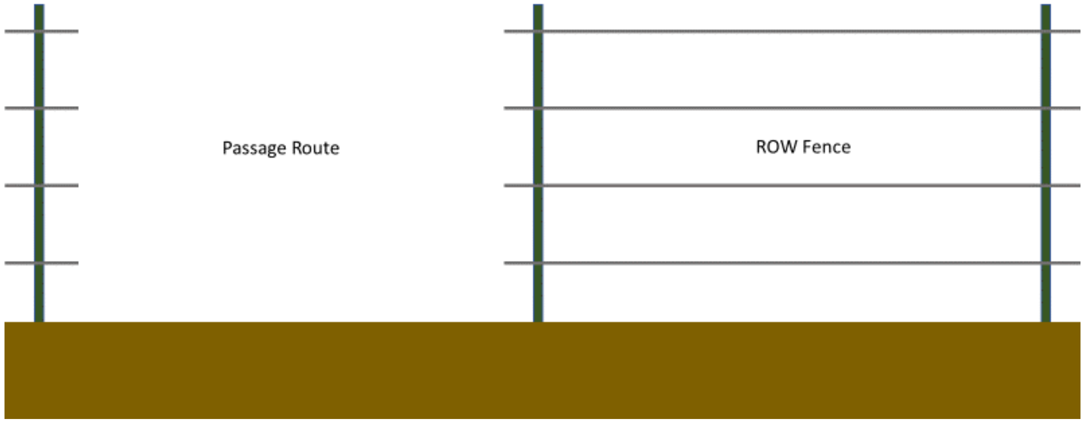


Figure 19. Diagram of a Fence Gap

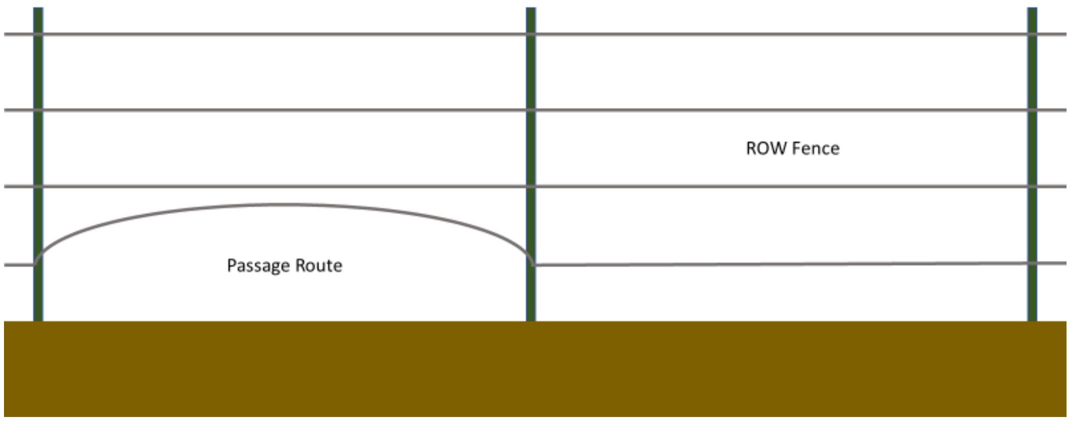


Figure 20. Diagram of a Raised Bottom Wire

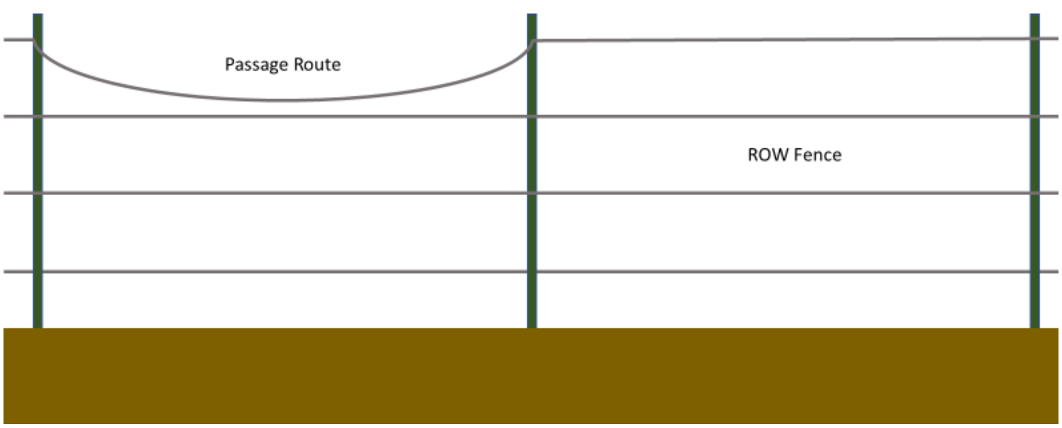


Figure 21. Diagram of a Low Top Wire

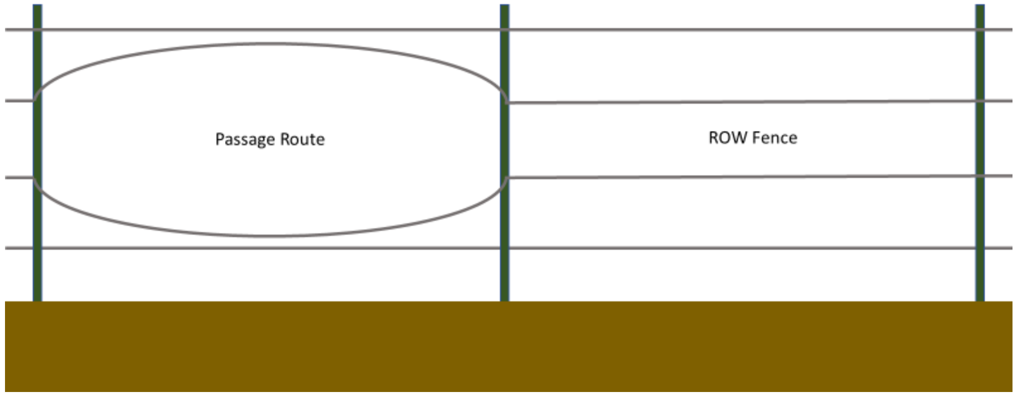


Figure 22. Diagram of a Between-Wire Gap

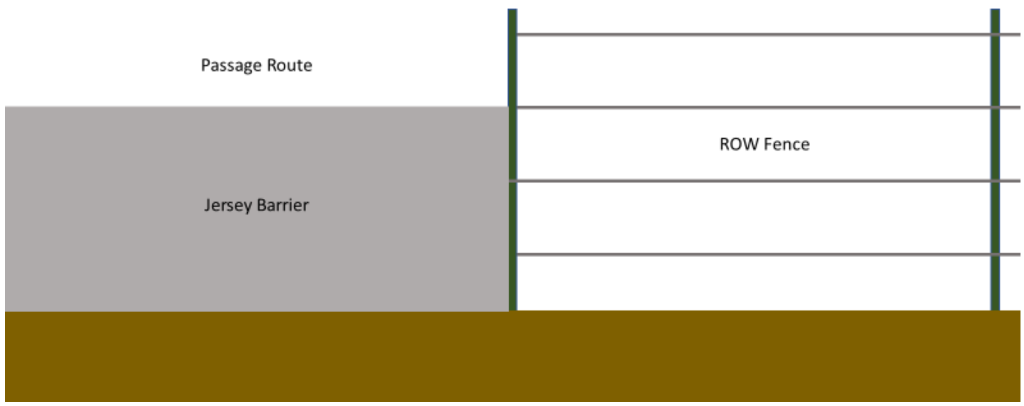


Figure 23. Diagram of a Jersey Barrier Tie-In

Still cameras were placed at 15 locations—two below-grade crossing structures, 12 potential ROW access points, and one crossing guard—along roadways within the study area (Figure 24):

- SR 74 (6 access points, 1 crossing guard)
- Loop 303 (2 access points)
- Castle Hot Springs Road (3 access points, 2 below-grade crossings)
- Lake Pleasant Parkway (1 access point)

Cameras were attached to adjacent fence posts using adjustable mounts that reduced the chance of theft and vandalism (Figure 25).

Source of map imagery: Esri

Figure 24. Camera Locations and Features Monitored

Figure 25. Still Camera Mounted to a Fence Post

Cameras were oriented to capture images as animals approached potential ROW access points from both directions (Figures 26 and 27). Once animals were detected, the cameras continued to collect images in increments of three images approximately 1 second apart until the animal left the camera's field of view. Cameras were monitored approximately every four weeks to replace batteries, collect images, ensure camera orientation was correct, and check for vandalism or theft. Images were backed up to an internal server and cloud storage platform to ensure data could not be lost in the event of equipment failure. If cameras were stolen or vandalized, a police report was filed and camera replacement was reevaluated to establish whether continued deployment would still be beneficial. Cameras in priority locations were replaced as soon as possible to avoid prolonged disruption in data collection.

Figure 26. Burros Approaching an ROW Access Feature from the Non-ROW Side

Figure 27. Burro Approaching an ROW Access Feature from the ROW Side

The research team processed images using the Rapid Analysis of Batched Image Data (RABID) application. RABID allows users to quickly sort and combine multiple images from one or more cameras into single events. This analysis allowed researchers to calculate the access point passage rate, which is the proportion of the number of times burros crossed an ROW structure to the number of times they approached the same structure. For example, if burros approached an ROW access point 100 times and crossed the structure 75 times, the access point passage rate for that structure would be 0.75, or 75 percent. This information was used to identify structural attributes (such as bottom wire height) that increase the risk of burros entering the ROW. Box culverts were also monitored in the study to determine whether burros used them.

SURVEY123 DATA: COLLECTION, REVIEW, AND ANALYSIS

The RABID images recorded the structural attributes of ROW access points and crossing structures with burro movements (Figure 28). Collected attributes included feature type, span, top wire height, bottom wire height, side of highway, surrounding fence type and height, passage width, traverse distance, ceiling height, substrate type, and presence of water. The structural attributes were used in combination with the still-camera data that informed the research team's recommendations for mitigating BVCs.

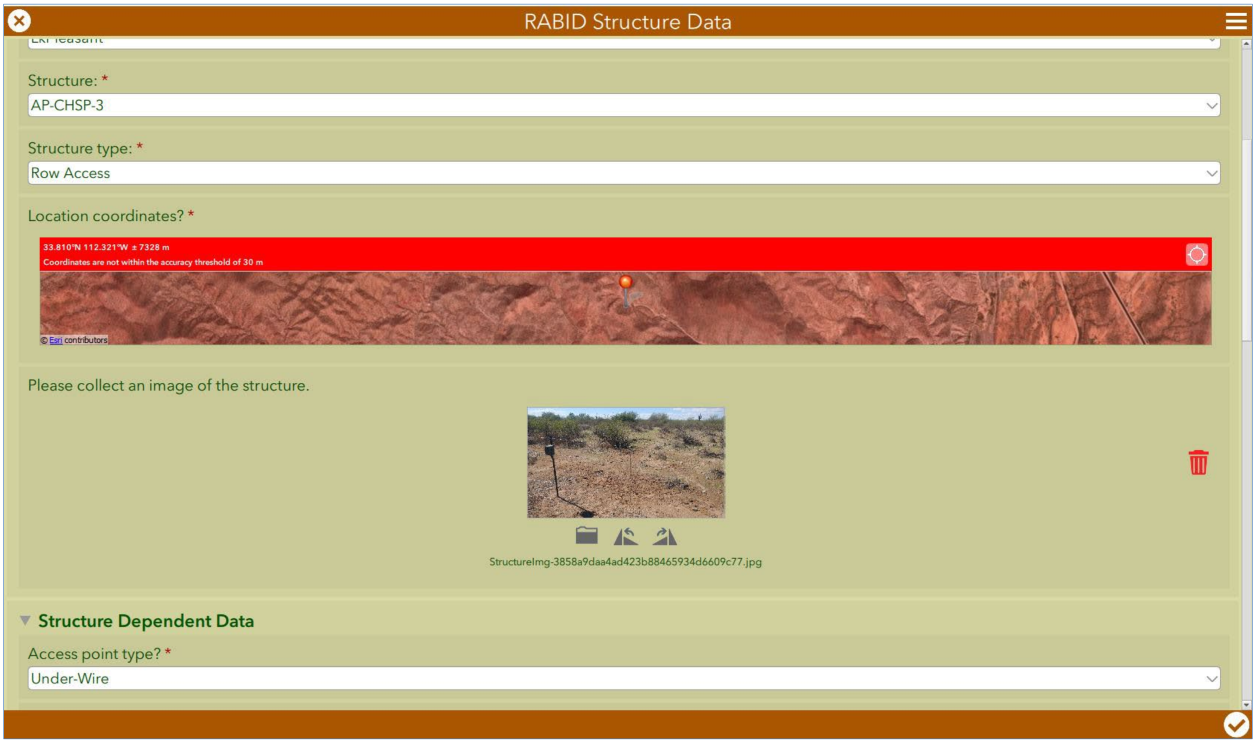


Figure 28. The RABID Structure Data Survey

BURRO CAPTURE, COLLARING, AND WELFARE

AGFD requested permission from BLM, the federal agency responsible for the protection of burros under the Wild Horse and Burro Act of 1971, to conduct the SPR-753 research study. The agency worked with BLM to select capture locations in accordance with the National Environmental Policy Act (NEPA) process and cultural compliance requirements.

In May 2016, AGFD received BLM approval to assist in the capture of burros with the conditions that all captures be conducted by BLM staff, or BLM-approved contractors, and that the USGS provide oversight of burro collaring until AGFD was adequately trained to collar burros. Since USGS was conducting its own study within the SPR-753 research study area, BLM required that burros for the SPR-753 and USGS studies be captured at the same time to reduce cost and effort to BLM. AGFD staff was also required to attend Comprehensive Animal Welfare Program training prior to handling any burros. To comply with the cultural resource requirement, BLM conducted archeological surveys, where appropriate. BLM granted approval to begin the SPR-753 research study in fall of 2016.

The research team purchased Lotek Iridium Trak M 2D GPS burro collars with VHF beacons for 25 jennies. Collars were programmed to collect 12 GPS locations daily at 2-hour intervals for 156 weeks, providing over 200,000 GPS locations total, to identify how and where burros interact with roads. Location data were programmed to transmit via Iridium satellite service every 36 hours, allowing remote data access and download via a portal website. Collars were outfitted with release mechanisms preset to 156 weeks after activation. These mechanisms can also be remotely released by the research team in situations when burro welfare is at stake due to collar failure.

To capture burros, BLM set up corral traps in areas where burros were recently present based on fresh burro signs or visual confirmation. Corral traps consisted of fence panels with a spring-loaded door (Figure 29). Traps were baited with alfalfa, and fishing line was placed as a trigger to close the door and trap the burros once they were feeding within the corral. The burros were then loaded into a trailer and transported and held at a processing location near Lake Pleasant (Figure 30). When burros were held at the processing location for several days, BLM staff provided feed and water. Burros from different capture locations remained segregated at the processing location. The burros were returned to their capture locations to allow adequate distribution of collared burros throughout the study area and record natural movement patterns.

Figure 29. Corral Trap with Spring-Loaded Door and Alfalfa as Bait

Figure 30. Burros Awaiting Processing at the Holding Location Near Lake Pleasant

In preparation for processing, burros were individually guided into a squeeze chute where they could be safely handled (Figure 31). Processing included collaring the animal, collecting a sample of tail hair for genetic testing, and applying a freeze brand with a unique identifier for future BLM reference (Figure 32). During processing, the research team collected information on sex, age, capture location, reproductive status, unique color patterns, time entering and exiting the chute, demeanor during collaring, presence of injuries or malformations, collar serial number, and collar frequency.

Figure 31. Burro Immobilized Within a Squeeze Chute at the Processing Site

Figure 32. Burro with Freeze Brand on Left Hip and Fitted Collar After Processing

Researchers only collared jennies that were at least three years old and from target locations based on study distribution requirements; the remaining animals were marked, sampled, and returned to the holding pen without collars. The collar was fitted to be loose enough to not choke the burro, but tight enough that it would not swing freely and cause injury to the jaw of the feeding animal (Figure 32). Once collared, the burro was released from the squeeze chute and placed back in the holding pen.

All burros were then loaded into a stock trailer, taken back to the capture location, and released. USGS personnel from Colorado helped collar the first burros and trained AGFD staff on best practices. Following the first round of captures, USGS deemed AGFD qualified to independently collar subsequent captures.

The first burros were captured and collared on February 1, 2017, and the last burro was captured and collared on July 10, 2018. Initial captures and collar deployments were drawn out because BLM staff was unavailable during prime trapping seasons. To mitigate the problem and avoid further delays, BLM hired a contractor in late June 2018 to meet the study sample requirement. In total, 26 burros were collared for the SPR-753 research study. To augment the study sample data, however, researchers also included GPS data from the USGS study of burros that interacted with roads within the SPR-753 study area.

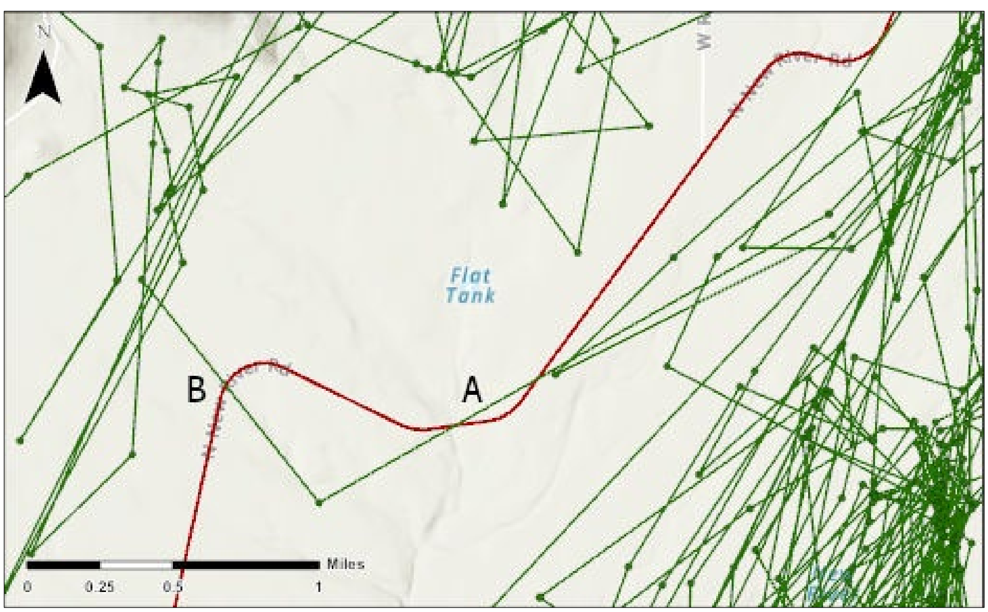
As part of the agreement with BLM, AGFD was required to conduct regular welfare checks on the SPR-753 collared burros to ensure no welfare issues were associated with the collars. AGFD utilized fixed-wing aircraft with VHF telemetry receivers to locate burros, and observers in the plane documented the animals' welfare status. If a burro appeared to be in distress due to the collar, the research team remotely released the collar.

BURRO MOVEMENT DATA: PROCESSING AND ANALYTICAL METHODS

Collars were retrieved and data downloaded when the GPS data collection period was complete, a burro welfare issue occurred, the GPS battery failed, or burro mortality occurred. Esri ArcGIS Pro software was used to plot, process, and analyze GPS location data.

The research team estimated the area occupied by individual burros (home range) during the study using 95 percent minimum convex polygons. The team calculated mean home range extents for jennies within the study area, identified herd associations, and determined the degree to which jennies used habitat adjacent to highways within the study area.

Consecutive point locations were connected with lines to approximate burro movement paths between points and inferred highway crossings where lines crossed highways between points on opposite sides (Figure 33; Dodd et al., 2007). These lines were used to calculate movement rates on several temporal scales (such as seasonal, monthly, or daily) to simulate burro activity peaks and investigate their relationship to observed burro-vehicle incident trends to help develop mitigation priority timelines.



Source of map imagery: Esri

Figure 33. GPS Locations of Burro Movement Paths and Highway Crossings (A and B)

The research team conducted a logistic regression analysis to determine what factors increased the odds of a burro crossing a highway. Variables were derived from fence inventory data, existing spatial data sets, and remote sensing layers, and values were allocated to each crossing according to a 0.15-mile buffer about the point at which movement lines intersected the highway.

To calculate crossing rates and identify peak crossing locations for individual collared burros, the research team divided the number of crossings by the days a collar was worn. Overall crossing frequency patterns were compared to hot spots for BVCs and were used as a variable in the logistic regression analysis.

Throughout the project, researchers used data from GPS collars to identify burro crossing locations along highways in the study area. Areas with relatively high burro crossings were investigated on the ground to determine if and how burros were accessing the ROW; researchers then informed ADOT or the appropriate jurisdiction of ROW access points and suggested immediate mitigation measures.

ROW FENCE DATA: COLLECTION, PROCESSING, AND ANALYTICAL METHODS

ROW fence surveys were conducted along all highways within the study area to further inform the BVCs and movement data analysis, guide still camera placement, and recommend mitigation measures. Between March 7 and June 30, 2017, the team mapped ROW barriers and unfenced easements along 72.7 miles of ROW, recording attributes that might impact permeability to burros, such as fence type or fence height. Additionally, researchers documented three classes of embedded features: potential ROW access points, gates, and crossing guards.

When fencing was not easily visible, fence inventories were conducted from alongside the road and sections were surveyed on foot. Fences were characterized from the start and end points of a segment, and an average value calculated for the segment. (An end point of a segment is determined when changes in feature characteristics were noted; a new segment is then started.) The research team took measurements and photographs at potential ROW access points.

The mobile geographic information system (GIS) applications collected data in a format compatible with ADOT's FIS. Collected data were processed in an ArcGIS Desktop environment using a geodatabase topology that detected anomalies, such as fences overlapping roads. The research team edited and developed a connected fence network. Embedded point features such as ROW access points, crossing guards, and gates were aligned to the fence network, and secondary reference attributes not collected in the field were appended to features (for example, highway name).

BVC SITE INVESTIGATIONS

The research team investigated BVC sites reported by ADOT, BLM, and AGFD staff, traveling to collision locations, conducting a walking survey of the ROW, confirming the incident location, documenting signs of the burro, and identifying burro access points (Figure 34). Investigation findings were entered into a report template with site-specific mitigation recommendations, which were distributed to ADOT's Central District environmental coordinator and maintenance yard.

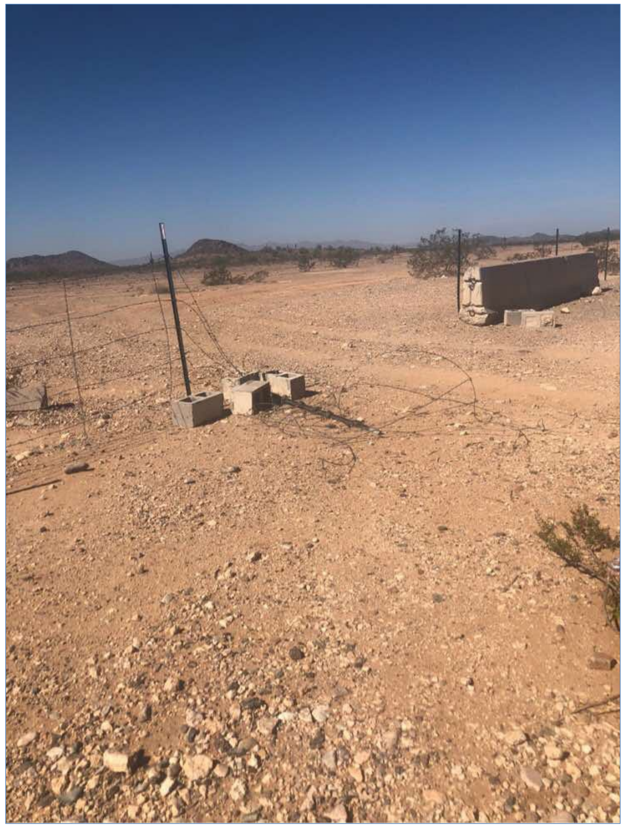


Figure 34. Burro-ROW Access Point Located During a BVC Site Investigation

The research team forwarded additional site-specific mitigation recommendations to ADOT throughout the study as team members encountered hazards such as cut fences, crossing guards filled with sediment, and burros in the ROW.

CHAPTER 4. DATA ANALYSIS AND RESULTS

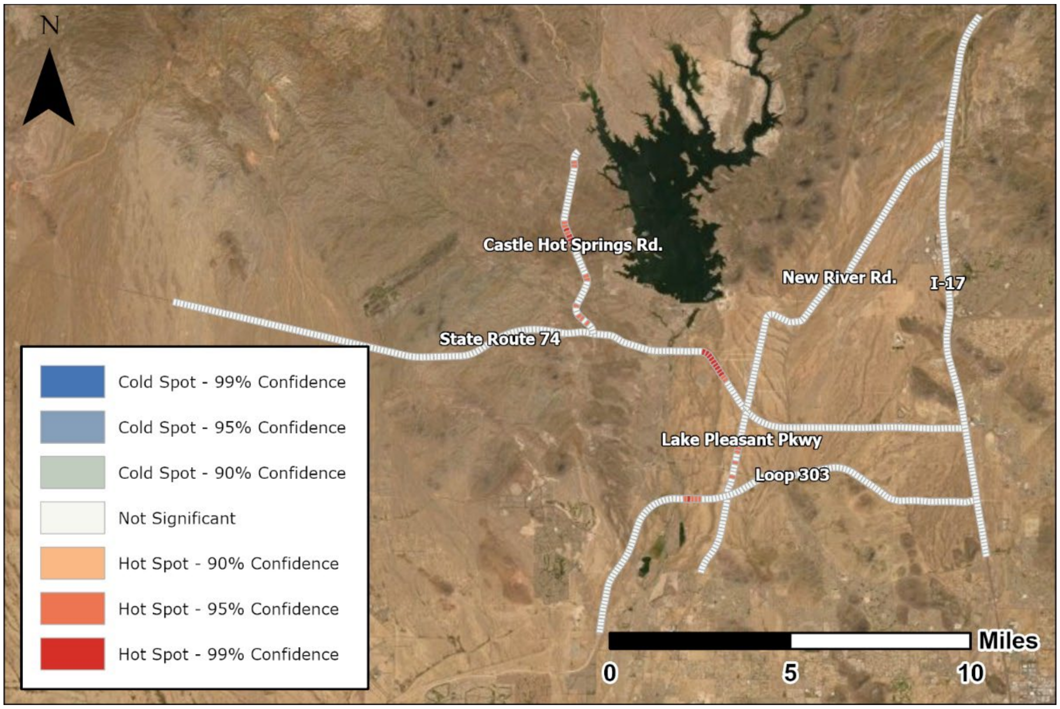
BVC RESULTS

Researchers analyzed 78 BVCs reported within 0.1-mile sections on highways in the study area (Table 4). A single BVC may represent one or multiple vehicles colliding with one or multiple burros at a given location and time.

Table 4. Baseline BVCs Data: 2014–2016

Highway	Jurisdiction	Length (mi)	BVCs	Annual BVCs/Mi
I-17	ADOT	15.3	2	0.044
Loop 303	ADOT	13.4	11	0.273
SR 74	ADOT	23.4	24	0.342
Castle Hot Springs Road	City of Peoria	5.6	23	1.381
Lake Pleasant Parkway	City of Peoria	4.7	11	0.777
New River Road	City of Phoenix	10.3	7	0.226
Total	**—**	**72.7**	**78**	**0.358**

While SR 74 and Castle Hot Springs Road had higher recorded collisions from 2014 to 2016 than any other highways in the study area, Castle Hot Springs Road and Lake Pleasant Parkway had the highest rates of BVCs per mile. A hot spot output for BVCs by 0.1-mile segment across the study area identified 37 out of 726 segments as hot spots (Figure 35). Hot spots were concentrated in portions of Castle Hot Springs Road, SR 74, Lake Pleasant Parkway, and Loop 303. These hot spots coincide with areas of high burro density within and adjacent to the LPHMA and with sections of damaged or compromised ROW fence.

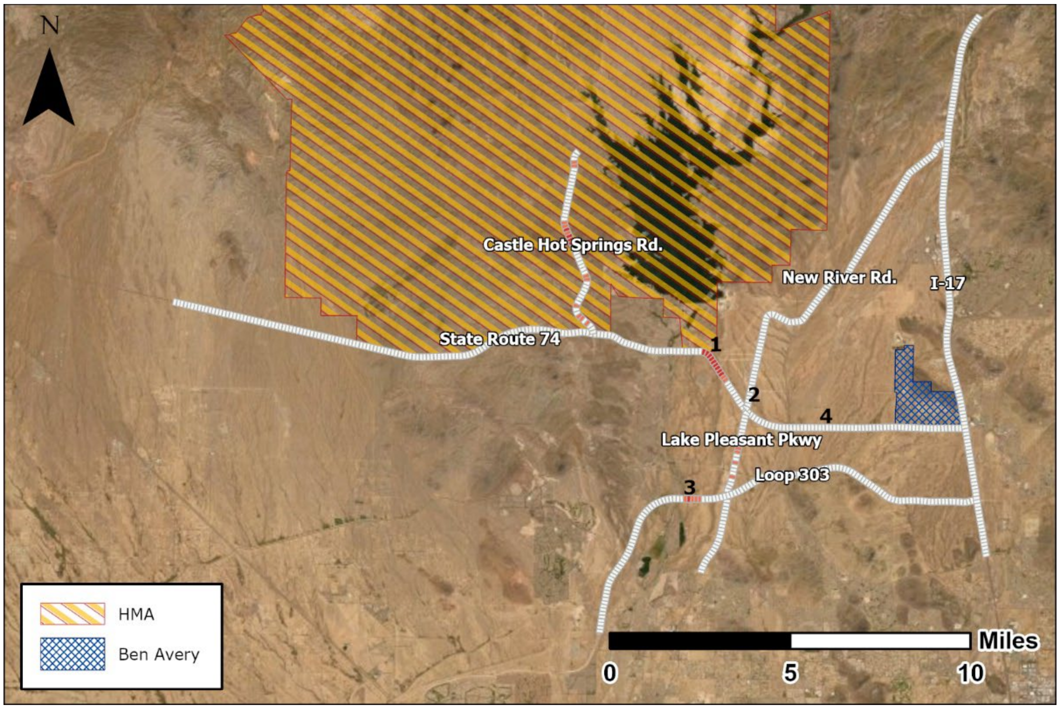


Source of map imagery: Esri

Figure 35. Hot Spot Analysis of Baseline BVCs Data

In early 2017, the research team worked with ADOT maintenance staff to begin BVC mitigation activities, which included completing an inventory of compromised ROW fence on ADOT highways. Team members referred to inventory results and hot spot analyses to prioritize fence repairs. ADOT maintenance repaired ROW fence gaps and cleared a crossing guard at location 1 (Figure 36), cleared a crossing guard at location 2, and installed chain-link fencing over a concrete Jersey barrier at location 3. In addition, ADOT completed the installation of chain-link ROW fence along the southbound lanes of I-17 between SR 74 and New River Road, and Southwest Asphalt repaired fence and tied a crossing guard into ROW fence at location 4.

At project inception, the research team began ongoing site investigations for all BVCs on ADOT highways within the study area to identify burro-ROW access points. Results of site investigations were reported to ADOT maintenance for immediate repair. The wide extent of mitigation measures on ADOT highways and the lack of mitigation implemented by other jurisdictions presented an opportunity to analyze the effect of responsive maintenance in reducing BVCs. Researchers conducted a comparative analysis of BVCs per mile between the baseline data from 2014 to 2016 (Table 5) and from 2017 to 2019 (Table 6).



Source of map imagery: Esri

Figure 36. Locations of BVC Mitigation Efforts

Table 5. BVC Data: 2017–2019

Highway	Jurisdiction	Extent (mi)	BVCs	Annual BVCs/Mi
I-17	ADOT	15.3	0	0.000
Loop 303	ADOT	13.4	1	0.025
SR 74	ADOT	23.4	6	0.086
Castle Hot Springs Road	City of Peoria	5.6	10	0.601
Lake Pleasant Parkway	City of Peoria	4.7	6	0.424
New River Road	City of Phoenix	10.3	1	0.032
Total	**—**	**72.7**	**24**	**0.110**

Fewer BVCs per mile were recorded from 2017 to 2019 compared to 2014 to 2016. Since the reduction in BVCs was seen across all highways in the study area, mitigation alone (which was focused on ADOT highways) cannot fully account for the difference. Reduction in BVCs for the 2017–2019 period may also be attributed to environmental factors, burro population trends, or changing traffic patterns.

Castle Hot Springs Road and Lake Pleasant Parkway recorded the highest rates of BVCs per mile in both periods (Table 6), as would be expected given the absence of mitigation on these highways. The average percent decrease in BVCs per mile across all six highways from 2014–2016 to 2017–2019 was 69.2 percent. A paired t-test showed that this decrease was statistically significant ($t = 3.738$, df 5, $p = 0.014$).

Table 6. Comparison of Annual BVCs Per Mile: 2014–2016 and 2017–2019

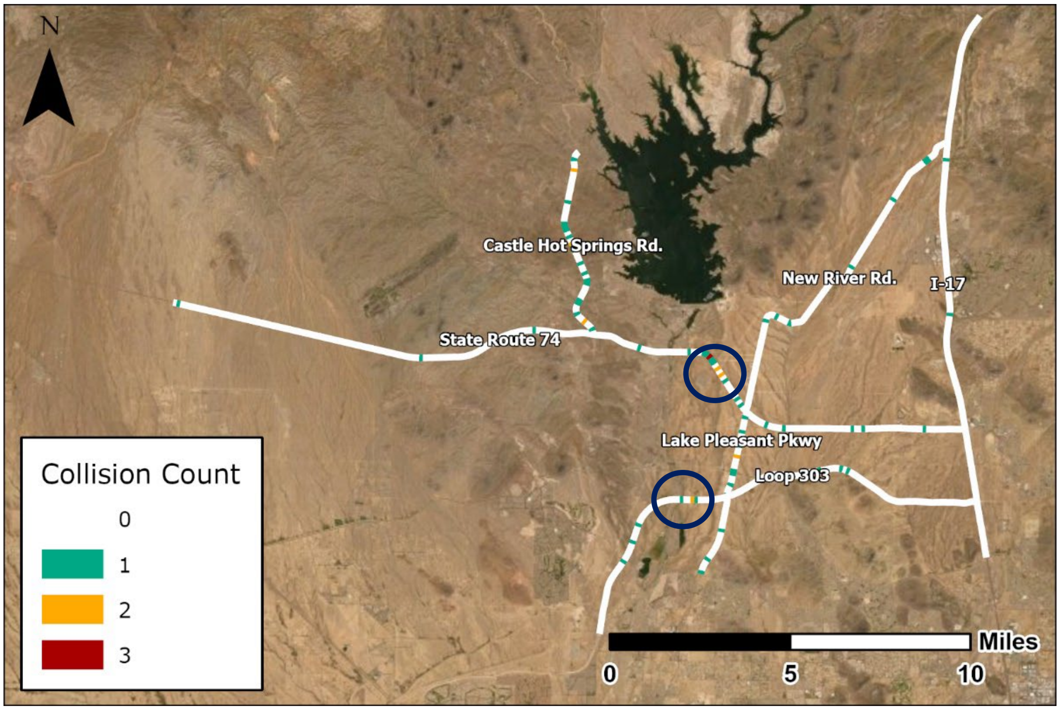
Highway	Jurisdiction	2014–2016 Annual BVCs/Mi	2017–2019 Annual BVCs/Mi	% Decrease
I-17	ADOT	0.044	0.000	100.0%
Loop 303	ADOT	0.273	0.025	90.9%
SR 74	ADOT	0.342	0.086	75.0%
Castle Hot Springs Road	City of Peoria	1.381	0.601	56.5%
Lake Pleasant Parkway	City of Peoria	0.777	0.424	45.5%
New River Road	City of Phoenix	0.226	0.032	85.7%
Overall	**—**	**0.358**	**0.110**	**69.2%**

The effect of mitigation on the decline in BVCs per mile was more pronounced when evaluated by jurisdiction. BVCs per mile decreased by 88.6 percent along ADOT highways (I-17, Loop 303, and SR 74), where mitigation efforts—ROW fence maintenance, fence repairs, and localized improvements such as cleaning of crossing guards—have been focused. City of Phoenix highways (New River Road) showed an 85.7 percent decrease, which may be attributed to the BLM's removal of more than 100 burros since 2015 (at least 81 of those were removed from the AGFD Ben Avery Shooting Facility) and may have contributed to the reduction in burro numbers between New River Road, I-17, and SR 74, where nearby burro removals have reduced an already low rate of collisions to near zero. (Only one BVC has been recorded on New River Road since 2015.) BVCs per mile on City of Peoria highways, where mitigation was not implemented, also declined by 52.5 percent.

The reported total number of BVCs, however, did not allow the research team to conduct pre-/post-Getis-Ord GI* hot spot analyses (minimum number required: 30). Instead, researchers conducted a 0.1-mile segment analysis. The reduction in BVCs across all highways between 2014–2016 (Figure 37) and 2017–2019 (Figure 38) is apparent, with the latter period showing much fewer segments with reported collisions. Sections of ADOT highway with clusters (circled) of BVCs in 2014–2016 did not occur in 2017–2019. BVCs on ADOT highways in 2014–2016 were concentrated in discrete areas, most apparent on SR 74 and associated with localized damage to ROW fence that were subsequently repaired by ADOT, suggesting that identification and repair of burro-ROW access points is important in reducing BVCs.

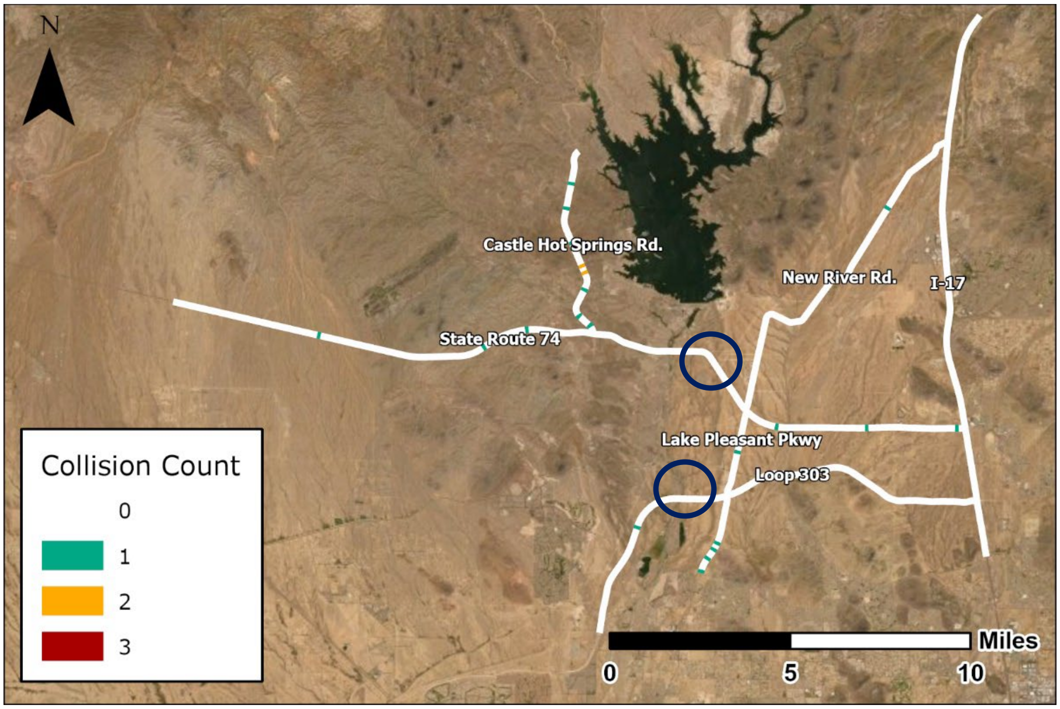
BVCs on Castle Hot Springs Road for both periods were widely spread throughout the length of the highway rather than clustered at certain points, which reflects the generally poor condition of ROW fence along the highway as noted during the fence inventory and its resultant permeability to burros.

The concentration of BVCs at the southern end of Lake Pleasant Parkway in 2017–2019 coincides with the terminus of ROW fence south of Loop 303 and represents the greatest concentration of BVCs outside of Castle Hot Springs Road since 2017. This finding demonstrates the value of ROW fence in reducing BVCs where burro populations are present.



Source of map imagery: Esri

Figure 37. Number of BVCs by 0.1-Mile Segments: 2014–2016 (Clusters of BVCs Circled)



Source of map imagery: Esri

Figure 38. Number of BVCs by 0.1-Mile Segments: 2017–2019 (Clusters of BVCs Circled)

To determine factors that increase the odds of a BVC hot spot, researchers conducted a logistic regression analysis. They analyzed the 37 highway segments identified as hot spots from the 2014–2016 hot spot output (Figure 35) alongside twice as many randomly selected nonhot spot segments. Segments on I-17 and New River Road were excluded as no hot spots have been identified on either highway. Each segment in the sample was characterized by nine highway attributes that determine the likelihood of BVCs occurring: highway type, fence top height, fence bottom height, distance to confirmed ROW access point types, distance to hydrological drainage crossing, curve, proximity to development, proximity to water, and proximity to highway intersections.

Five attributes were statistically significant (p-value <0.05): highway type, fence top height, fence bottom height, distance to confirmed ROW access point types, and distance to hydrological drainage crossing (Table 7). If the odds ratio and the 95 percent CI for a given highway attribute are greater than 1.0, the influencing factor (characterized by the first option in column 2) is considered to be significant. For example, a segment within 0.25 mile of a confirmed ROW access point (such as unfenced highway, fence gaps, and access point types with passage rates greater than 10 percent) is 7.95 times more likely to be a hot spot than a segment greater than 0.25 mile from an access point. The statistical significance of the odds ratios was tested using the Wald chi-square test at p-value <0.05 with a 95 percent CI.

Table 7. Logistic Regression Analysis of Hot Spots by Spatial Attributes of Highway Segments

Attribute	Options	Wald Chi-Square	P-Value	Odds Ratio	95% CI	Influencing Factor
Highway type	Non-ADOT vs. ADOT	9.13	<0.01*	4.76	2.03-11.18	Non-ADOT
Fence top height	<42” vs. >42”	7.96	<0.01*	3.5	1.47-8.36	<42”
Fence bottom height	>16” or absent vs. <16”	10.19	<0.01*	9.65	2.40-38.80	>16” or absent
Distance to confirmed ROW access point types	<0.25 mi vs. >0.25 mi	15.03	<0.01*	7.95	2.79-22.68	<0.25 mi
Distance to hydrological drainage crossing	>0.25 mi vs. <0.25 mi	10.93	<0.01*	4.09	1.78-9.45	>0.25 mi
Curve (sinuosity index)	<1.02 vs. >1.02	0.12	0.73	1.20	0.44-3.30	None
Distance to development	<0.25 mi vs. >0.25 mi	0.94	0.33	1.73	0.57-5.25	None
Distance to water source	>0.25 mi vs. <0.25 mi	1.91	0.17	4.48	0.53-37.69	None
Distance to highway intersection	<0.25 mi vs. >0.25 mi	0.47	0.49	1.41	0.53-3.81	None

*Statistically significant.

In summary, hot spot highway segments are characterized by:

- Fences with top wire heights below 42 inches
- Fences with bottom wire heights above 16 inches or absent
- Areas within 0.25 mile of documented ROW access points
- Areas that are more than 0.25 mile from locations where hydrological drainages cross over or under the ROW

Fence characteristics suggest that standard ADOT game fence maintained to specifications will effectively exclude burros from accessing the ROW. The higher odds of a BVC hot spot occurring within 0.25 mile of an ROW access point indicate the need for regular fence surveys and prompt maintenance to reduce BVCs. The reduced likelihood of a hot spot in proximity (<0.25 mile) to hydrological drainages was unexpected but may coincide with the locations of culverts large enough for burros to pass through. This finding could suggest that burros prefer to use below-grade crossings via culverts and beneath bridges versus attempting at-grade crossings within the ROW, which is explored with the GPS movement data presented later in this chapter.

CAMERA DATA COLLECTION RESULTS

Twelve potential ROW access points were monitored within the study area to assess their permeability to burros: one crossing guard, two unguarded driveways (where an access road crosses the ROW fence without a guard), one barrier arm gate, one fence gap, two raised bottom wires, two low top wires, one between-wire gap, and two Jersey barrier tie-ins. In addition, to support interpretation of the burro movement data presented later in this chapter, two box culverts were monitored to determine whether burros used them for below-grade highway crossings.

Cameras captured images of all burros as they approached monitored structures in these areas. Researchers analyzed these images to calculate the access point passage rate. To help interpret the burro movement data, they used the passage rate for an ROW access point to identify types of structural attributes (such as bottom wire height) that increased the risk of burros entering the ROW. The structure passage rate for a below-grade crossing structure was used to determine how readily burros would utilize these structures to cross highways without entering the ROW, which created a BVC risk.

From July 2017 through December 2019, researchers collected 602,815 images, documenting 302 burro approaches to below-grade crossing structures and 671 approaches to potential ROW access points (973 total burro approaches).

The 302 burro approaches to monitored below-grade crossing structures resulted in 251 successful crossings, a structure passage rate of 83 percent, which shows that burros regularly and willingly use below-grade crossing structures to cross paved highways (Figures 39 and 40). At one of the monitored structures (UP-LPB-2), below-grade crossings were in proximity to a regularly used ROW access point (Figure 41), demonstrating that while burros are expected to utilize below-grade crossing structures, the presence of a below-grade crossing structure did not prevent the burros from entering the ROW where the ROW fence is compromised.

Figure 39. Burro Approaching a Below-Grade Crossing Structure

Figure 40. Burros Exiting a Below-Grade Crossing Structure

Figure 41. Burro Leaving an ROW Through a Raised Bottom Wire Adjacent to a Below-Grade Crossing Structure

The 671 burro approaches to ROW access points comprise images of 419 burro approaches to raised bottom wires, 178 to fence gaps, 26 to crossing guards, 15 to unguarded driveways, 14 to low top wires, 14 to Jersey barrier tie-ins, and 5 to between-wire gaps. No approaches to barrier arm gates were documented.

Table 8 shows overall crossing and access point passage rates for each type of ROW access point. Access point passage rates were highest at fence gaps (97 percent), raised bottom wires (60 percent), and unguarded driveways (40 percent). (Note: Access point passage rates at unguarded driveways were lower than at fence gaps not associated with driveways. The two access point types are structurally similar except for the presence of vehicle traffic through the unguarded driveway, which suggests that vehicle traffic itself acts as a deterrent to burro use.) Crossing guards successfully repelled burros in all 26 documented instances. One crossing was recorded at the low top wire access point, which has a top wire height of 74 cm (29.1 inches), lower than the 127 cm (50 inches) height of the surrounding ROW fence. The burro failed to clear the 74 cm (29.1 inches) height without getting entangled in the fence (Figure 42), which suggests that the propensity and ability of burros to jump over ROW fence are limited and that heights lower than 127 cm (50 inches) may exclude burros from the ROW.

Table 8. Total Approaches, Crossings, and Passage Rates at ROW Access Points (2017–2019)

Access Point Type	Total Approaches	Total Crossings	Passage Rate
Raised bottom wire	419	253	60.4%
Fence gap	178	173	97.2%
Crossing guard	26	0	0.0%
Unguarded driveway	15	6	40.0%
Low top wire	14	1	7.1%
Jersey barrier tie-in	14	0	0.0%
Between-wire gap	5	0	0.0%
Barrier arm gate	0	0	Not available
Total	**671**	**433**	—

Figure 42. Burro Crossing a Low Top Wire Access Point

Access point passage rates were determined for ROW entries (a burro crosses a feature into the ROW from outside of the ROW) and escapes (a burro crosses a feature out of the ROW from inside the ROW) (Table 9). For fence gaps, passage rates were 97 percent for both ROW entries and escapes, which suggests that burros will freely enter and exit the ROW where fence gaps exist and that vehicle traffic does not deter burros from entering an ROW when fence gaps exist. Passage rates for raised bottom wire access points were relatively high for ROW entries (64 percent) and escapes (57 percent), suggesting that burros can pass relatively freely across raised bottom wire access points.

At unguarded driveways, passage rates were much higher for ROW escapes (80 percent) than for entries (20 percent), suggesting that vehicle traffic may deter ROW entry. Passage rates for ROW escapes could not be calculated for between-wire gap and Jersey barrier tie-in access points because there were no documented burro approaches at these access point types.

Table 9. Access Point Passage Rates for ROW Entries and Escapes

Access Point Type	ROW Entry Passage Rate	ROW Escape Passage Rate
Fence gap	97%	97.4%
Raised bottom wire	64.2%	56.5%
Low top wire	25%	0%
Unguarded driveway	20%	80%

In November 2018, the bottom wire height was modified at the two raised bottom wire access points monitored in the study area. The new height was 10 cm (3.9 inches) lower than the original height at each access point (from 0.92 m (36.2 inches) to 0.82 m (32.3 inches) at one structure (AP-LPB-2) and from 0.73 m (28.7 inches) to 0.63 m (24.8 inches) at the second structure (AP-LPB-3)). Both structures were monitored until February 2020, which allowed a before and after measurement of the passage rate (Table 10).

Table 10. Passage Rates at Raised Bottom Wire Access Points Before and After Bottom Wire Height Modification

Structure Name	Premodification Passage Rate	Postmodification Passage Rate
AP-LPB-2	35.8%	30.0%
AP-LPB-3	84.1%	82.1%

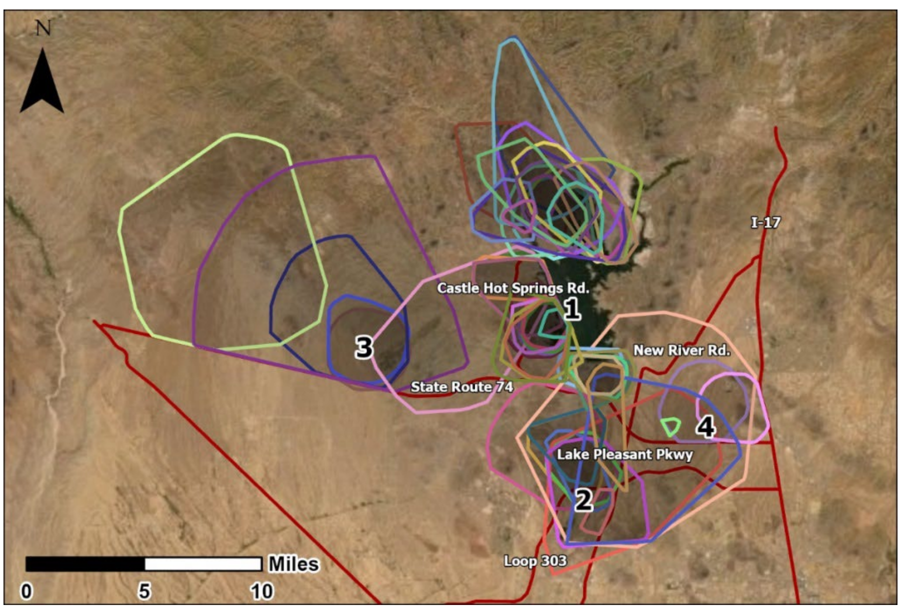
Burros continued to cross the ROW fence at both locations even after the height modifications. Reductions in passage rates, however, were documented at both access points and suggested that a reduction in bottom wire height can reduce burros' ability to access ROW. Further investigation is needed to determine the maximum height that can effectively exclude burros from entering the ROW. Moreover, while the bottom wire heights were higher at AP-LPB-2, the passage rates were higher at AP-LPB-3, which suggests that other site-specific factors may influence passage rates.

BURRO GPS MOVEMENT DATA RESULTS

Data from the GPS collars of 56 jennies were extracted and analyzed to show the relationship between burro movements and their behaviors to BVC patterns. Overall, data collection averaged 710 days (ranging from a minimum of 15 days to a maximum of 1138 days) from February 1, 2017, through January 11, 2021, and encompassed 336,629 GPS locations.

Burro Habitat Use

Figure 43 shows the burro habitat use patterns representing home ranges or areas where the study burros regularly travel to search for food or to mate. A home range is represented by the convex polygons estimated to encompass 95 percent of the area occupied by a burro. The total estimated home ranges cover 171,763 acres of the study area, with a mean home range size of 9361 acres (standard deviation = 11,178). The median home range is 5330 acres, ranging from a minimum of 778 acres to a maximum of 51,756 acres.

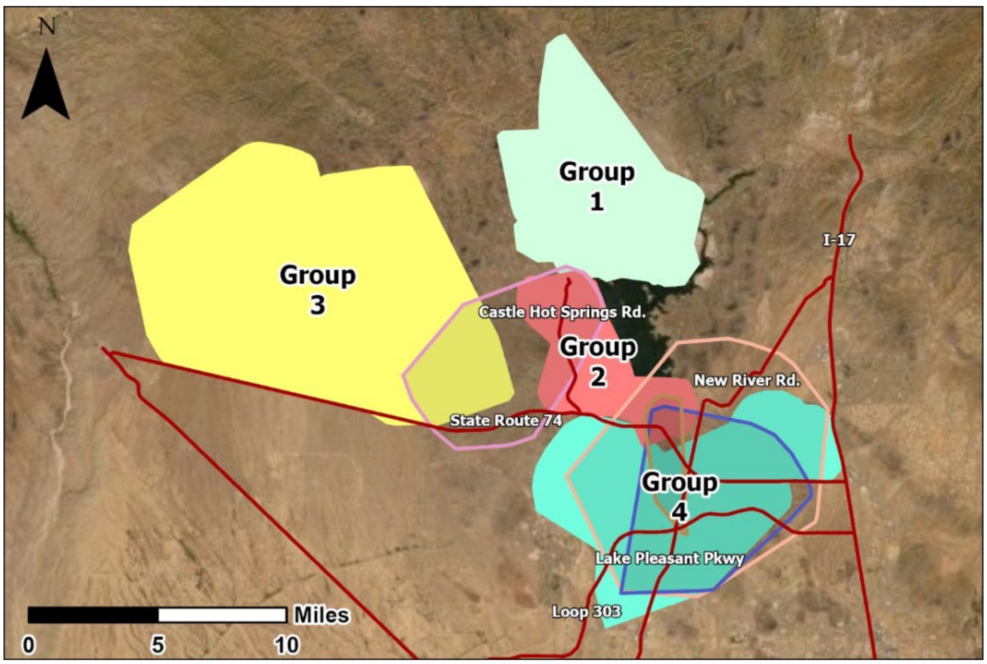


Source of map imagery: Esri

Figure 43. Burro Home Ranges Represented by 95 Percent Minimum Convex Polygons (Colored outlines: individual home ranges; numbers: perennial water sources)

The extensive home range overlap shown in Figure 44 shows existing herd associations near perennial water sources, including Lake Pleasant (location 1), Agua Fria drainage and associated canals (location 2), Quintero Resort (location 3), and Southwest Asphalt plant and AGFD Ben Avery Shooting Facility along SR 74 (location 4).

Four geographic groupings of home ranges were discerned from the data (Figure 44). Each group shows minimal to no interaction with other groups. Group 1 incorporated 18 home ranges, group 2 incorporated 18, group 3 incorporated five, and group 4 incorporated 11. All groups were concentrated around the four perennial water sources. Groups 2, 3, and 4 are bounded in part by SR 74 where ADOT game fence is relatively impermeable to burro passage.



Source of map imagery: Esri

Figure 44. Burro Range Groupings (Solid Polygons) and Transient Individuals Between Groups (Hollow Polygons)

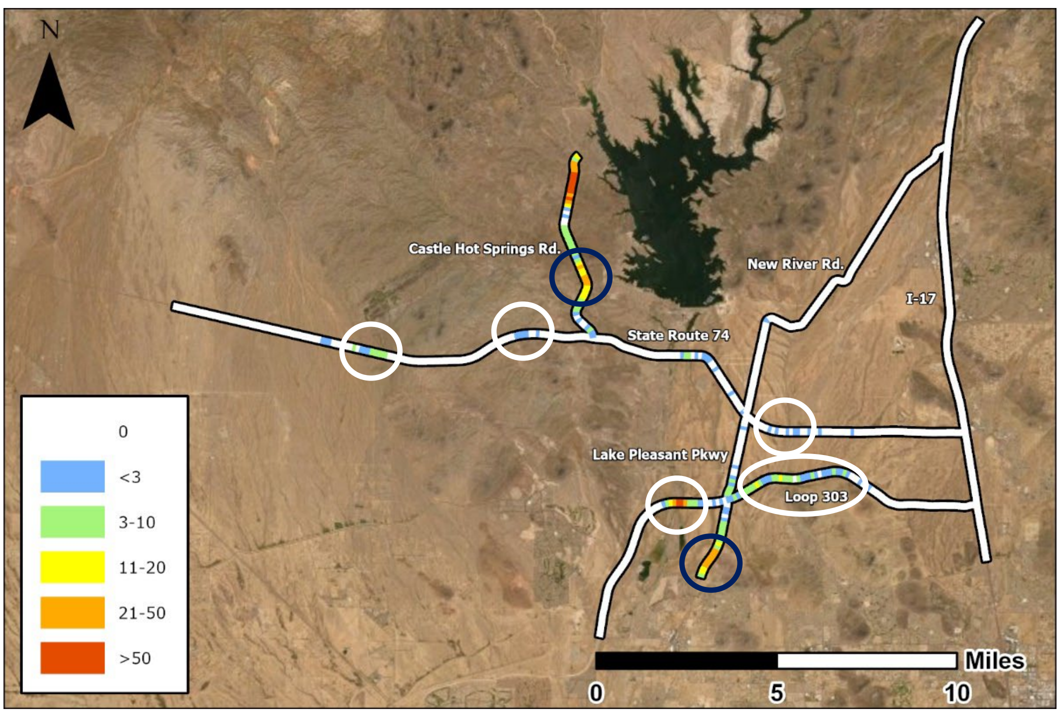
Relative to location density, 38.7 percent of the total area occupied by burros was within LPHMA, accounting for75.3 percent (253,504) of the total recorded burro locations. This translates to a location density of 3.81 locations per acre of occupied burro range within LPHMA against 0.76 locations per acre outside of LPHMA over the course of the project. Occupied burro habitat within 1000 m (0.62 miles) of a highway accounted for 21.3 percent of total occupied habitat, while 56.6 miles of highway (38.5 miles of

ADOT ROW) are within or directly adjacent to occupied burro habitat. Burros regularly use highway adjacent habitat, thereby increasing the odds of encountering ROW access points.

Burro-Highway Interactions

A subset of the sample data (38 jennies) that entered within a 1000 m (0.62 miles) buffer of highways in the study area was analyzed to examine burro-highway interactions, highway permeability, and the relationship between ROW fencing and BVCs patterns. It incorporated 195,131 GPS locations.

Burro-highway crossings within the study area were mapped and analyzed by 0.1-mile segments (Figure 45). Across the study area, 86 0.1-mile highway segments accounted for at least one collision from 2014 to 2019. Of these, 30 0.1-mile highway segments (34.9 percent) were crossed at least three times by collared burros. Nine of the 30 segments (30 percent) had at least one documented collision. As shown in Figure 45, considerable overlap occurred between the burro crossing locations and BVC locations (dark blue circles) within the City of Peoria jurisdiction and minimal overlap (white circles) along the ADOT jurisdiction. These relationships suggest a difference in the nature of the crossings that occurred on ADOT highways compared to those on City of Peoria highways.



Source of map imagery: Esri

Figure 45. Number of Burro-Highway Crossings by 0.1-Mile Highway Segment (Dark blue circles: areas of major overlap between crossings and collisions; white circles: areas with minimal overlap)

The highway crossing passage rate is a measure of how easily burros can cross a barrier (in this case, a highway). The passage rate represents the proportion of the number of times burros crossed a 0.1-mile segment of highway to the number of times they approached within 250 m (820.2 feet) of the highway. In succeeding paragraphs, passage rates were calculated by highway and by the entire study area, and then assessed against highway and environmental factors.

From 2017 to 2021, jennies made 4858 highway approaches and completed 1879 highway crossings, with an overall passage rate of 38.7 percent (standard error of the mean = 0.05). ADOT highways accounted for 47.7 percent of total approaches and 25.9 percent of crossings; City of Peoria highways accounted for 51.1 percent of approaches and 74 percent of crossings. Passage rates were 20.9 percent on highways within the ADOT jurisdiction, 45.7 percent within the City of Peoria jurisdiction, and 33.4 percent within the City of Phoenix jurisdiction. City of Peoria highways are twice as permeable to burros compared to ADOT highways, which may be attributed to the incomplete ROW fencing or fencing in poorer condition found along the City of Peoria highways.

Among the six highways included in the study, Castle Hot Springs Road had the highest approaches per mile, crossings per mile, and passage rate (Table 11). Passage rates and crossings per mile were also high for Loop 303 and Lake Pleasant Parkway, while approaches per mile were high for Loop 303, SR 74, and Lake Pleasant Parkway. For non-ADOT highways (Castle Hot Springs Road, Lake Pleasant Parkway, and New River Road), highways with the highest crossings matched those identified in the baseline BVCs data as having the highest BVCs. For ADOT highways, no clear relationship between BVCs and crossings per mile was observed.

According to the baseline BVC data, Castle Hot Springs Road and Lake Pleasant Parkway consistently recorded the highest number of annual collisions per mile, while I-17, Loop 303, and New River Road have consistently recorded the lowest number of annual collisions per mile. For non-ADOT highways, BVCs were highest where crossings were highest.

Table 11. All Highways: Approaches, Crossings, and Passage Rates Per Mile (2017–2021)

Highway	Approaches Per Mile	Crossings Per Mile	Passage Rate
I-17	1.3	0.0	0.0%
Loop 303	64.3	31.0	48.1%
SR 74	61.3	3.0	5.0%
Castle Hot Springs Road	326.1	199.6	61.2%
Lake Pleasant Parkway	139.8	58.1	41.6%
New River Road	5.7	0.0	0.0%
Total	**66.8**	**25.8**	**38.6%**

For Loop 303, 37.1 percent of approaches occurred in 0.1-mile segments with below-grade structures (culverts or viaducts), which could explain the high burro crossings. These segments accounted for 52.8 percent of crossings and passage rates that are nearly double those for segments without culverts (Table 12). While a high number of crossings occurred on Loop 303, they did not result in a high number of collisions.

Table 12. Loop 303: Approaches, Crossings, and Passage Rates (2017–2021)

Activity	Overall	With Below-Grade Structure	Without Below-Grade Structure
Approaches	860	319	541
Crossings	413	218	195
Passage rate	48%	68.3%	36%

For Lake Pleasant Parkway (Table 13), 83.2 percent of crossings occurred across unfenced segments with a passage rate of 56 percent. Burro crossings (14.7 percent) across segments with intact fence (fence without ROW access points) had a passage rate of 17.2 percent. While 6.5 percent of approaches to the highway occurred in segments with a below-grade structure, 69.8 percent resulted in a crossing. These statistics emphasize the importance of ROW fencing and maintenance in excluding burros from ROW, while also demonstrating burros' ability to use below-grade crossings.

Table 13. Lake Pleasant Parkway: Approaches, Crossings, and Passage Rates (2017–2021)

Activity	Overall	Unfenced	Intact Fence	Below-Grade Structure
Approaches	657	405	233	43
Crossings	273	227	40	30
Passage rate	41.6%	56%	17.2%	69.8%

Burro crossings on Castle Hot Springs Road showed no clear pattern in relation to highway factors, although overall passage rates were higher (greater than 50 percent) compared with other highways. This reflects the highly permeable nature of the highway due to the high number of ROW access points and generally poor condition of ROW fence along Castle Hot Springs Road.

On non-ADOT highways (Castle Hot Springs Road, Lake Pleasant Parkway, and New River Road), collisions increased as crossings increased, and unfenced ROW and ROW access points enabled more crossings than intact ROW fence. Crossings on non-ADOT highways occurred at grade with a high potential of collisions while crossings on ADOT highways generally occurred below grade with no potential of collisions. ADOT highways are fully fenced and have a higher level of ROW fence maintenance relative to Castle Hot Springs Road and Lake Pleasant Parkway.

Temporal Trends to Burro-Highway Interactions

No clear relationships were discerned between BVCs, approaches, crossings, and highway passage rates by day of the week and highway or jurisdiction for data collected from 2017 to 2021.

Burro-highway approaches and crossings were highest from late fall into spring and lowest from late spring through summer (Figures 46 and 47, respectively). These patterns broadly reflect those observed for BVCs in the baseline BVC data.

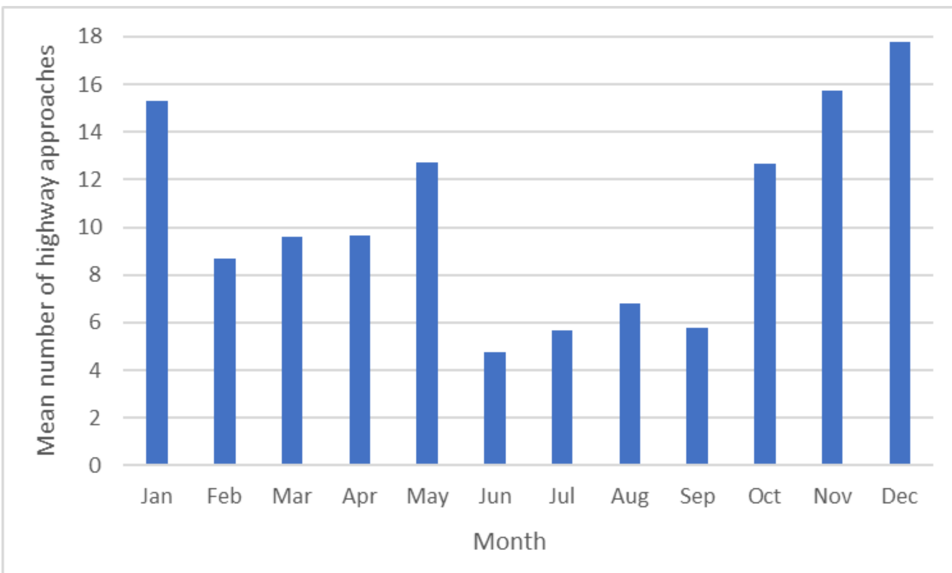


Figure 46. Mean Number of Highway Approaches for All Burros Across All Highways (February 1, 2017, through January 11, 2021)

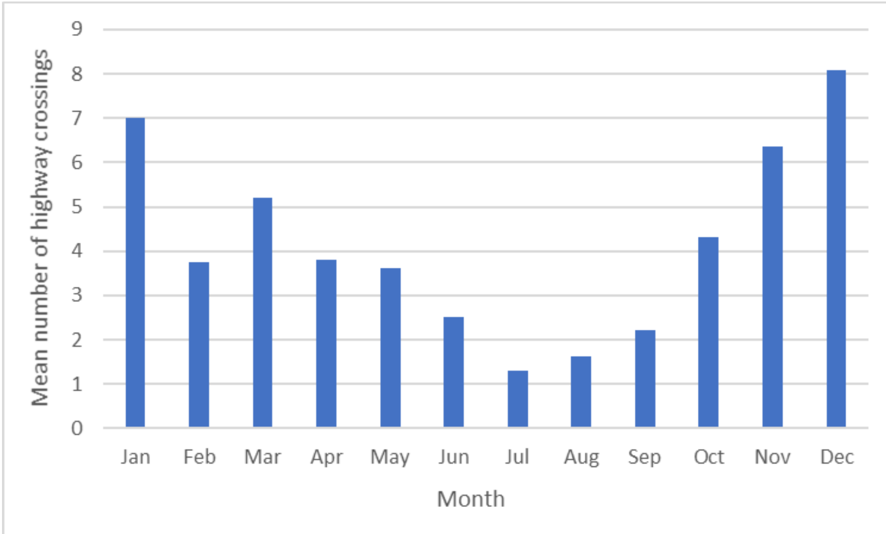


Figure 47. Mean Number of Highway Crossings for All Burros Across All Highways (February 1, 2017, through January 11, 2021)

Monthly highway passage rates were highest from late fall through early spring and lowest from late spring through the summer except in June when burros move to exploit new foraging opportunities and water resources before the monsoon season (Figure 48). Approaches, crossings and passage rate patterns suggest a different movement pattern during hotter, drier periods of the year and reduced burro-highway interactions during these periods.

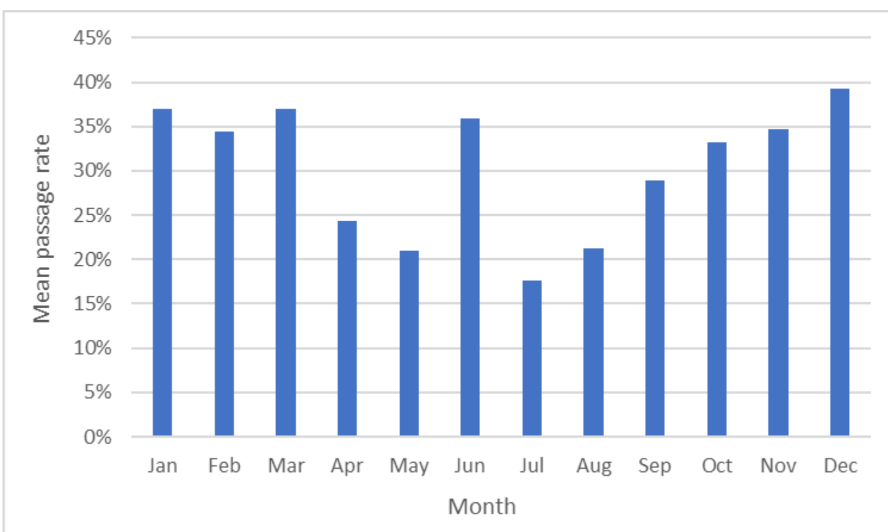


Figure 48. Mean Highway Passage Rates for All Burros Across All Highways (February 1, 2017, through January 11, 2021)

Temporal Trends to Burro Movements

Hourly movement distances of all 56 jennies were assessed by day of the week to evaluate relationships between burro behaviors and weekly variations in collisions. Very little variation was documented in mean hourly distance covered by day, averaging 156.7 m (514.1 feet) with a narrow range from 154.2 m (505.9 feet) to 159.4 m (523.0 feet) (Figure 49). Given this relatively low distance covered per hour, other factors such as changes in traffic patterns and motorist behaviors may play a bigger role in BVCs than burro behavior alone.

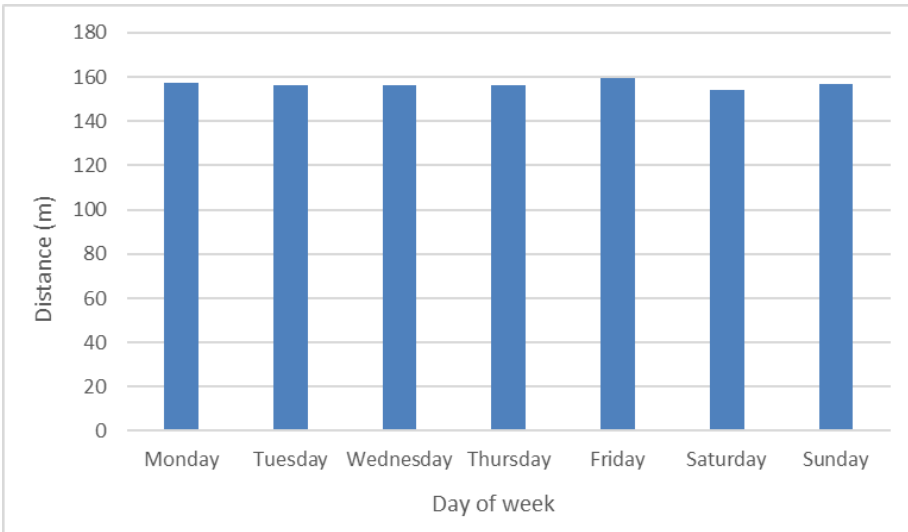


Figure 49. Mean Hourly Movement Distance by Day of the Week (February 1, 2017, through January 11, 2021)

When assessing mean hourly movement distances by month (Figure 50), movement rates decreased from May through July. Movement rates ranged from a low of 132.7 meters per hour in June to a high of 176.2 meters per hour in November. While differences in hourly movement rates between months were not as high as for collisions and crossings, the overall patterns were broadly similar. These patterns supported the finding of reduced burro movement during the hotter, drier periods of the year, resulting in reduced burro-highway interactions during these periods and a lower rate of BVCs.

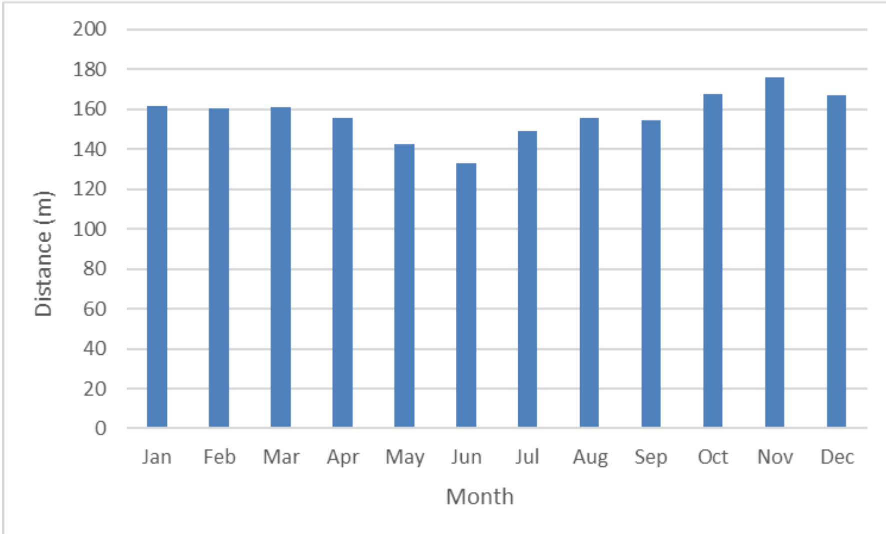


Figure 50. Mean Hourly Movement Distance by Month (February 1, 2017, through January 11, 2021)

Factors Influencing Burro-Highway Crossings

To determine the factors that increase the odds of burro crossings across a 0.1-mile highway segment, the research team conducted a logistic regression analysis by highway attribute (Table 14). Of the nine highway attributes used in the analysis, three were statistically significant (p-value <0.05): highway type, fence top height, and distance to confirmed ROW access point types. The statistical significance of the odds ratios was tested using the Wald chi-square test at p-value <0.05 with a 95 percent CI.

If the odds ratio for an attribute is greater than 1.0, the influencing factor is given by the first option shown in column 2. For example, a segment within (less than) 0.25 mile of a confirmed ROW access point (such as an unfenced highway, fence gaps, and access point types with access point passage rates greater than 10 percent) is 2.46 times more likely to have three or more burro crossings than a segment greater than 0.25 mile from an access point.

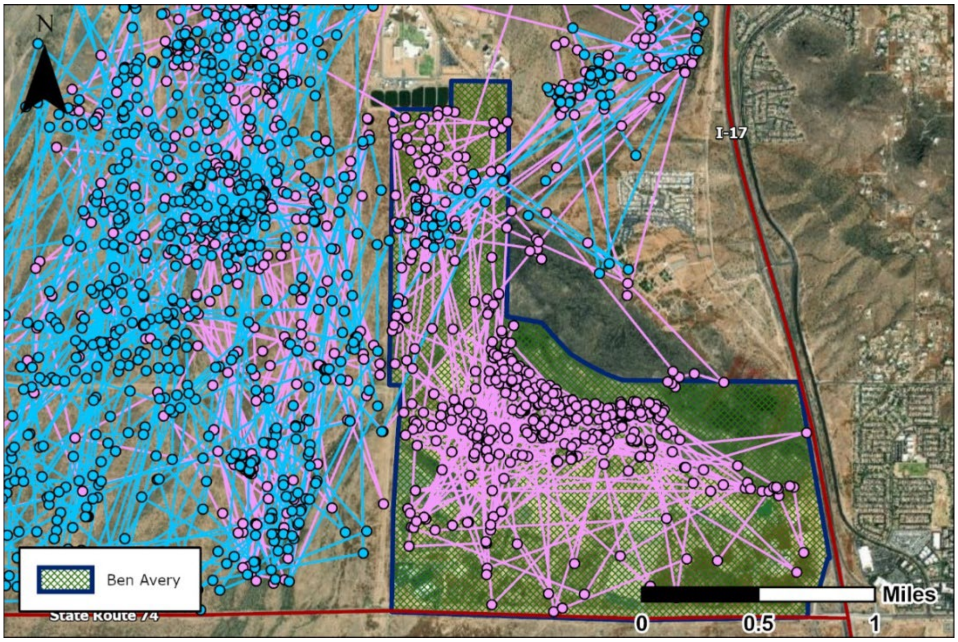
Table 14. Logistic Regression Analysis of 0.1-Mile Segments with Three or More Crossings

Attribute	Options	Wald Chi-Square	P-Value	Odds Ratio	95% CI	Influencing Factor
Highway type	Non-ADOT vs. ADOT	80.29	<0.01*	22.78	11.5-45.12	Non-ADOT
Fence top height	<42” vs. >42”	43.9	<0.01*	9.47	4.87-18.43	<42”
Distance to confirmed ROW access point types	<0.25 mi vs. >0.25 mi	15.38	<0.01*	2.76	1.66-4.59	<0.25 mi
Fence bottom height	>16” or absent vs. <16”	2.34	0.13	1.85	0.84-4.06	None
Distance to hydrological drainage crossing	>0.25 mi vs. <0.25 mi	0.49	0.49	1.2	0.72-2.02	None
Curve (sinuosity index)	<1.02 vs. >1.02	1.13	0.29	1.35	0.78-2.37	None
Distance to development	<0.25 mi vs. >0.25 mi	2.34	0.13	1.58	0.88-2.83	None
Distance to water source	>0.25 mi vs. <0.25 mi	0.02	0.9	1.05	0.5-2.21	None
Distance to highway intersection	<0.25 mi vs. >0.25 mi	0	1	1	0.55-1.83	None

In summary, highway segments with three or more crossings are characterized by fences with a top wire height below 42 inches within 0.25 mile of documented ROW access points and are generally outside of ADOT jurisdiction. A top wire height below 42 inches reflects the co-occurrence of Jersey barrier and below-grade crossing structures. It implies the need to create and maintain standard game fence specifications along ROW in BVC-related areas throughout Arizona. The influence of ROW access points on burro crossings reflects the highly porous nature of ROW fence outside of ADOT jurisdiction, namely, compromised ROW fence along Castle Hot Springs Road and unfenced ROW along portions of Lake Pleasant Parkway.

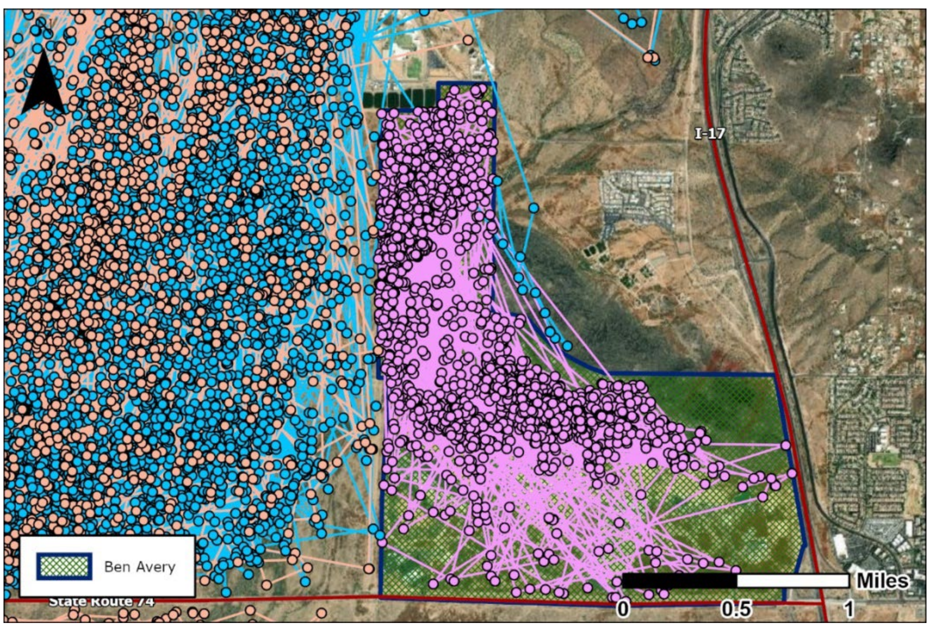
Case Study: Effectiveness of Fencing in Preventing Burro Passage

AGFD’s Ben Avery Shooting Facility is a case study site that demonstrates the effectiveness of ADOT game fence for preventing burro passage. The property line of the facility is fenced with four-strand barbed wire fence matching standard ADOT game fencing. Prior to November 2018, two collared burros occupied portions of the facility, accessing the property via two equestrian gates and a washed-out section of fence in the northern portion of the facility (Figure 51). In November 2018, AGFD staff modified the equestrian gates and repaired the compromised fence to prevent burro passage. After these repairs were completed, one collared burro was penned within the facility and two nearby collared burros were excluded. Despite reliable water sources on the property and the limited range available to the burro enclosed on the facility, no collared burros crossed the property line for the remainder of the project (Figure 52). The burro enclosed on the property remained for seven months until removed during a BLM nuisance gather in July 2019, which confirms that ADOT game fence effectively prevents burro passage when complete and maintained.



Source of map imagery: Esri

Figure 51. Burro Locations and Inferred Movement Paths On and Near the Ben Avery Shooting Facility Before Fence Modification (November 2018)



Source of map imagery: Esri

Figure 52. Burro Locations and Inferred Movement Paths On and Near the Ben Avery Shooting Facility After Fence Modification (November 2018)

CHAPTER 5. DISCUSSION AND CONCLUSIONS

BURRO MOVEMENTS AND BEHAVIORS

Because burros are a nonnative species with the potential to negatively impact native wildlife (Danvir 2018), connectivity goals for these animals differ from those for native wildlife species. The Wild Free-Roaming Horses and Burros Act of 1971 provides protections for burro populations and directives to manage them as an integral part of the natural system within HMAs but not outside of these areas. As such, population management approaches to BVC mitigation outside of HMAs may not be feasible within HMAs and may differ from mitigation approaches typically recommended for native wildlife species. Burros' inability to cross wildlife fence (which is traversable by native wildlife, as identified from camera and movement data) presents the opportunity to restrict burro movements without restricting wildlife connectivity.

While burro populations within the study area were concentrated within LPHMA, the burro range extended far beyond LPHMA's boundaries. From 2014 to 2019, BVCs outside of the HMA accounted for 72.8 percent of total BVCs along ADOT roads and 55.9 percent of BVCs within the study area. Thus, restricting the burro range outside of LPHMA could significantly reduce BVCs. Burro home ranges were bounded by fenced highways in many areas, and burro populations were concentrated around permanent water sources. Incorporating existing fenced highway into landscape-level exclusion plans and restricting burro access to water sources may effectively restrict burro range and reduce the geographical extent of highway at risk of BVCs.

About 57 miles of highway within the study area were found in proximity (less than 1000 m (0.62 miles)) to burro range, elevating the risk of burros encountering ROW access points, if present. These sections of highway accounted for 93.1 percent of BVCs between 2014 and 2019.

Seasonal variations in burro movement rates, highway approaches between 2017 and 2021, and BVCs between 2014 and 2019 suggest that BVC risk is at its greatest from October through January and lowest from June to August. Mitigation efforts implemented before BVC peak periods may minimize the impact of these seasonal factors.

BURRO-HIGHWAY CROSSINGS

Burro-highway crossings in the study area occurred at grade within the ROW and below grade through culverts and viaducts.

At-Grade Crossings

Lake Pleasant Parkway was the only highway in the study area with unfenced ROW in burro habitat. The unfenced sections of this road had a highway passage rate of 56 percent compared to 17.2 percent on sections of the road with intact fence. From 2017 to 2019, 50 percent of BVCs recorded outside of LPHMA occurred in the unfenced sections of Lake Pleasant Parkway. Unfenced highway and compromised ROW fence facilitate at-grade highway crossings and inflate BVC rates.

Below-Grade Crossings

Below-grade crossings occurred where large drainage culverts and viaducts allowed burros to cross beneath highways without entering the ROW (Figure 53). Below-grade crossings did not directly contribute to increased rates of BVCs in their immediate vicinity. However, below-grade crossings allow burros to access areas adjacent to roads where they would not usually access, exposing these areas to BVC risk. The structure passage rate at below-grade highway crossings exceeded 80 percent, which demonstrates that burro habitat connectivity within HMAs would not be impaired by ROW fence improvement.

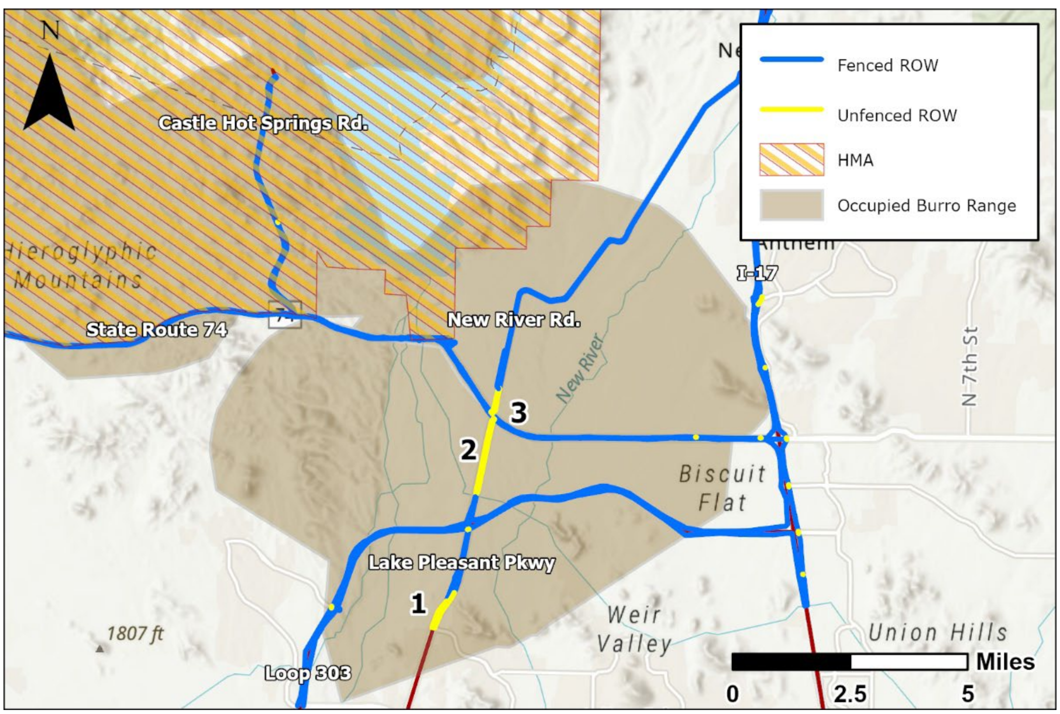
Figure 53. Burro Using a Below-Grade Drainage Structure to Cross a Highway

Installing wildlife-friendly fence or barriers across below-grade structures that enable burros to access areas outside LPHMA could effectively isolate burro populations outside LPHMA. If fence or barrier installation were combined with BLM nuisance burro gathers, these isolated populations could be removed, as demonstrated by the case study presented in Chapter 4, potentially reducing the burro range dramatically and restricting the extent of highway at risk of BVCs.

Burro Range Restriction

In the Lake Pleasant area, upgrading and maintaining ROW fence along the western frontages of Lake Pleasant Parkway and New River Road would be the simplest exclusion strategy to implement (Figure 54). A 3200-foot extension of ROW fence along the southbound lanes of Lake Pleasant Parkway and a 4600-foot extension along the northbound lanes of Lake Pleasant Parkway south to Westwing Parkway would be required with tie-ins (Location 1) to development boundaries at the southern extent. A single box culvert would also need to be fenced within this section. Along New River Road, a 2700-foot extension of ROW fence would be required along the southbound lanes north from SR 74 to a private property boundary and a 3000-foot extension along the northbound lanes to the current fence terminus with full tie-ins (Location 2). No new fence would be required at Location 3 as the Beardsley Canal to the west provides a barrier to burro movement.

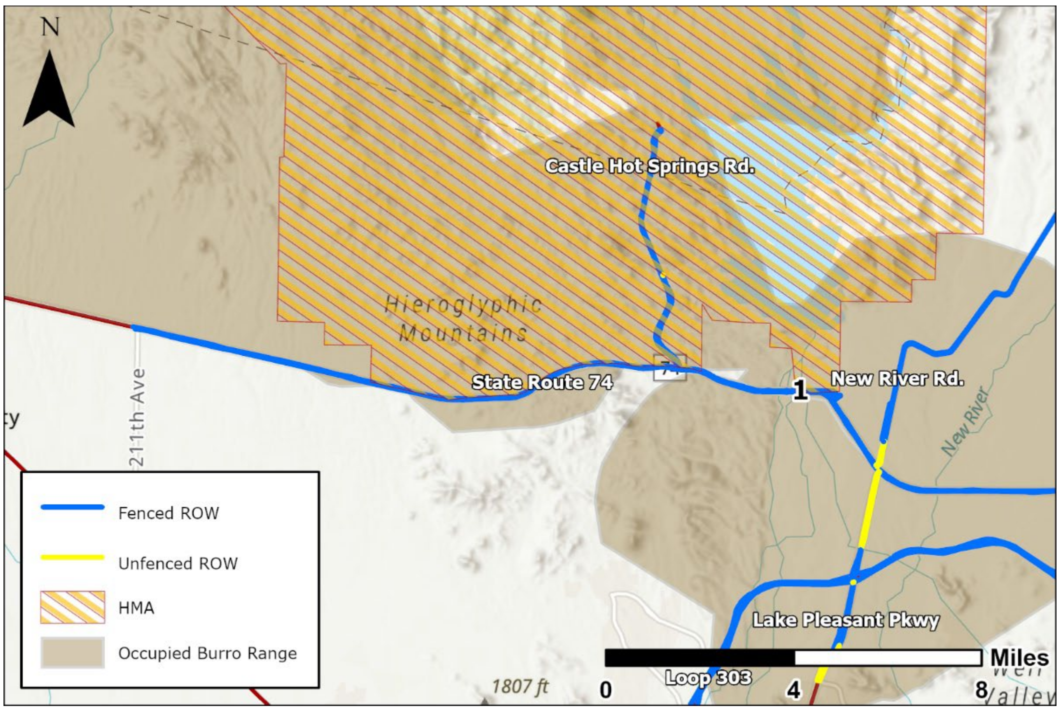
Once fence upgrades were complete, a BLM nuisance gather would be necessary to remove the burros within the exclusion. This mitigation would reduce the burro range in the study area by over 25,000 acres, removing over 14 percent of occupied burro range in the study area. From 2014 to 2019, burros within this range accounted for at least 20 percent of BVCs and possibly as high as 37 percent, depending on which side of the highway burros accessed the ROW along the boundaries.



Source of map imagery: Esri

Figure 54. Burro Exclusion and Removal Opportunities Along Lake Pleasant Parkway and New River Road

An additional restriction effort could be undertaken along the northern frontage of the remaining extent of SR 74 West from New River Road to exclude burros from all range south of SR 74 (Figure 55). Several box culverts would need to be spanned but the greatest obstacle would be preventing below-grade crossings of SR 74 at the Agua Fria drainage below Lake Pleasant dam (Location 1). If this effort were implemented along with removal gathers within the exclusion, an additional 21,000 acres of occupied burro range could be removed for a combined reduction of over 46,000 acres, or 27 percent, of the currently occupied range. Burros within this range accounted for at least 38 percent of BVCs from 2014 to 2019, although that figure could be as high as 68 percent.



Source of map imagery: Esri

Figure 55. Burro Exclusion and Removal Opportunities Along SR 74

ROW ACCESS POINTS

BVCs hot spots are strongly associated with ROW access points (Figure 56), which allow burros to cross fences and enter ROW. Burros were shown to access ROW through unfenced sections of highway, through gaps in ROW fence, under raised bottom wires, through unguarded driveways and intersections, and across sediment-filled crossing guards. Each of these access points is discussed below followed by a discussion of gate design and burro interactions.

Figure 56. Burro Jack That Entered a Fenced ROW Through an Access Point

Unfenced Highway

As discussed in the At-Grade Crossings section, unfenced highway is not an effective deterrent to burros. If only one side of an ROW is fenced, burros can enter and become trapped within the ROW.

Fence Gaps

Remote camera evaluations of gaps in ROW fence showed that burros entered ROW through fence gaps at a passage rate of 97.2 percent. Highway sections with fence gaps were also strongly associated with BVCs, possibly because the intact fence guides burros to these gaps where they can access previously unexplored habitat. Gaps in ROW fence typically occur where sections of the fence are cut to allow off-highway vehicle (OHV) access (Figure 57), are blown out across a wash by flowing water and debris (Figure 58), and have heavy vegetation encroachment.

Figure 57. ROW Fence Cut to Access a Nearby OHV Trail

Figure 58. ROW Fence Blowout Across a Wash Caused by a Flood

Cuts in ROW fence to facilitate OHV access were typically made where fences are easily accessible from the paved highway and close to unpaved roads or lands closed to public use, often near locked gates (Figure 59).

Figure 59. Cut ROW Fence Adjacent to a Locked Gate

ROW fence blowouts occur in areas with sporadic high-volume water flow, typically where fences cross washes. Debris becomes entangled in the fence, and the force of water acting on these obstacles can dislodge and destroy large sections of fence. Vegetation encroachment was also seen to lead to fence gaps where trees or cacti growing near ROW fence fall or drop limbs onto the fence and cause damage.

As of the 2017 fence inventory, fence gaps on ADOT highways were twice as common along barbed wire ROW fence than along chain-link fence (0.14 fence gaps per mile of barbed wire fence and 0.07 gaps per mile of chain-link fence). Cutting barbed wire fence is relatively easy compared to cutting chain-link fence. Also, short sections of barbed wire fence are often incorporated within stretches of chain-link to bridge drainage features, exposing them to greater risk of fence blowout (Figure 60). Finally, chain-link fence within the study area is located in areas difficult to access from the paved ROW and with fewer unpaved roads nearby, reducing the incentive to cut chain-link fence.

Figure 60. Section of Barbed Wire Fence Within a Chain-Link ROW Fence to Bridge a Drainage Feature

Raised Bottom Wires

Burros were unable to pass beneath ADOT game fence with bottom wire heights of 18 inches above ground level. There was no evidence that burros can cross over ROW fence that meets the standard ADOT game fence's 42-inch top-wire height. However, burros regularly passed beneath fence with nonstandard bottom wire heights. Raised bottom wires over 24 inches above ground level were monitored during the study. Passage rates across these access points exceeded 60 percent, representing the third most used ROW access point type within the study area after unfenced highway and fence gaps.

Raised bottom wires in the study area were exclusive to barbed wire fence designs and were most common where topography changed dramatically over short distances. Within the study area this situation was most common where ROW fence entered steep-sided washes, creating a raised gap beneath the more elevated side of the fence span (Figure 61). Since barbed wire fence is often incorporated into chain-link fence to bridge drainage features, installing chain-link or woven wire fences is not expected to reduce the incidence of raised bottom wire access points.

Figure 61. Raised Bottom Wire Access Point Where Fence Enters a Wash

Unguarded Driveways and Intersections

Burros crossed ROW fence through driveways without crossing guards (Figure 62), however, passage rates for these access points were only 20 percent. Burros more commonly used these features to escape ROW. Nonetheless, where surrounding ROW fence is well maintained, these features present a risk of burro-ROW entry, which may result in BVCs.

Figure 62. An Unguarded Driveway

Crossing Guards

Single crossing guards with a width of 8 feet and vaults with less than 50 percent sedimentation effectively prevented burro-ROW access in all 26 instances documented by cameras. Burro movement data and BVC patterns did not suggest that burros entered ROW via crossing guards when sedimentation levels were maintained below 50 percent. At the beginning of the project, two crossing guards with more than 50 percent sedimentation were associated with BVC hot spots from the baseline period (2014 to 2016) (Figure 63). ADOT cleared these guards while repairing nearby fences. During the project period (2017 to 2019), these areas were no longer BVC hot spots. Previous studies also found that crossing guards with deeper pits present a more substantial barrier to ungulates than those with shallower pits (Huijser et al. 2015).

Figure 63. Crossing Guard with More Than 50 Percent Sedimentation

Gates

Camera monitoring of gates failed to document burro-gate interactions over the course of the project. However, anecdotal observations suggest that certain gate designs may be permeable to burros given the physical similarities of these gates to known ROW access point types. Similarly, unclosed gates are analogous to unguarded driveways and represent a risk for burro-ROW entry.

Single-arm gate designs (Figure 64) or designs including large apertures within the structure such as equestrian gates (Figure 65) present a potential burro passage route similar to a raised bottom wire. Anecdotally, a research biologist from AGFD noted that equestrian gate designs with a bar close to ground level and an aperture directly above were observed to allow burro passage (Colin Beach, personal communications, October 5, 2018). Staff at the Ben Avery Shooting Facility added welded metal to two equestrian gates previously observed to allow burro passage to close these apertures (Figure 66). As noted in the case study in Chapter 4, no collared burros were documented crossing the fence after modification.

Figure 64. Single-Arm Gate with a Gap Greater Than 24 Inches Beneath the Bottom Bar

Figure 65. Equestrian Gate with an Aperture Allowing Burro Passage

Figure 66. Modified Equestrian Gate to Prevent Burro Passage Through Aperture

Unclosed gates are an intermittent but recurring issue. Given the unpredictability of when gates might be left open it was not possible to monitor unclosed gates for burro passage within the study area. However, an unclosed and unguarded gate represents a potential burro-ROW access point analogous to a fence gap or unguarded driveway (Figure 67).

Figure 67. Unclosed Gate at ROW Access Point

CHAPTER 6. RECOMMENDATIONS

The 88.6 percent reduction in BVCs on ADOT highways during the project period indicated that mitigation efforts can contribute to dramatic reductions in BVCs. As the LPHMA continues to support a dense burro population near several highways, complete elimination of BVCs within the study area poses a challenge. To address recurring BVCs, mitigation strategies related to the following topics could be considered:

- Burro population management
- Fence and barrier installation and maintenance
- Burro highway crossings
- Burro-ROW entry and collision reporting
- Interagency coordination
- Additional research into burro behavior and BVC patterns

BURRO POPULATION MANAGEMENT

The most effective BVC mitigation method is reducing and restricting burro populations wherever feasible. Below are suggested strategies for consideration:

- Advocate for BLM to maintain burro population levels below the maximum AML within HMAs. Maintaining LPHMA burro populations at or below the upper AML and restricting burros to as confined an area around LPHMA as possible could reduce BVCs in the study area by more than 50 percent and reduce fence survey and maintenance workloads.
- Advocate for BLM to remove nuisance burros outside of HMAs.
- Facilitate the BLM burro adoption program where possible. Explore opportunities to increase burro adoption rates and reduce capacity for removal gathers. Options may include increasing program exposure through internal and external publications, leveraging programmable signage to increase awareness of BVCs and burro adoption opportunities, or incorporating BVC information and links to the burro adoption program on ADOT’s website.
- Consider implementing the burro exclusion plans described in Chapter 5 for the Lake Pleasant and other BVC problem areas.

- Improve and extend ROW fence to restrict burro movements from HMAs onto surrounding lands. Developing burro exclusion zones outside of HMAs that incorporate fenced ROW and prevent below-grade highway crossings could dramatically reduce BVCs.
- Restrict burro access to permanent water sources outside of HMAs.

FENCE AND BARRIER INSTALLATION AND MAINTENANCE

Below are recommendations that ADOT may use for ROW fencing along highways and wash crossings, and for using crossing guards, gates, and fence ends. Additional guidance presents strategies to prevent trespassing, conduct fence surveys, and perform maintenance. The specifications outlined below use ADOT fence details as the standard specifications. Other measures are noted where ADOT standard details may not be sufficient to prevent burro passage.

ROW Fence Design

When burro population removal is not feasible, ROW fence is the most effective BVC mitigation available. In unfenced areas where BVCs are a concern, consider installing fences on both sides of the highway. If only one side of the ROW is fenced, install fencing along the unfenced side of the ROW.

Raised bottom wires can be effectively mitigated by four main methods, which may be used in combination:

- Install a deadweight hang (a heavy object attached to the fence) intended to pull the fence closer to ground level and anchor fence posts (Figure 68).
- Install additional wires beneath the standard four strands (Figure 69).
- Span the gap with a single fence span and hanging material cut to length beneath the fence (Figure 70).
- Shorten fence spans that traverse steep topography so the fence posts are installed and anchored as close to the top and toe of a slope as possible and wire hung between the posts runs parallel to the ground.

Whichever configuration is used, the modified bottom wire height should not exceed 18 inches above ground level. Wherever nonstandard fence additions are installed, document them in a referenceable format to ensure future repairs at the location incorporate similar measures.

Given the initial installation cost, difficulty of repair, impermeability to other wildlife, and the effectiveness of standard ADOT game fence in keeping burros off the road, large-scale replacement of barbed wire game fence with chain-link fence is not considered a cost-effective mitigation for BVC in most cases.

In summary:

- Fence ROW wherever possible.
- Install standard ADOT barbed-wire game fence in all BVC-related areas.
- Maintain top wire heights at 42 inches above ground level throughout.
- Maintain bottom wire heights at 18 inches above ground level throughout.
- Ensure all fence spans include an adequate number of stays.
- Install one of the described mitigations (Figures 68 to 70) where fences traverse dramatic topographical changes.
- Where Jersey barrier functions as ROW fence, top or back it with barbed wire or chain-link fence to discourage burros from climbing over the barrier.
- Document the location and design of nonstandard fence additions in a referenceable format to ensure future repairs at the location incorporate similar measures.

Figure 68. Deadweight Hang Anchoring a Fence Post Where ROW Fence Spans a Wash

Figure 69. Additional Strand of Wire Beneath a Four-Strand ROW Fence

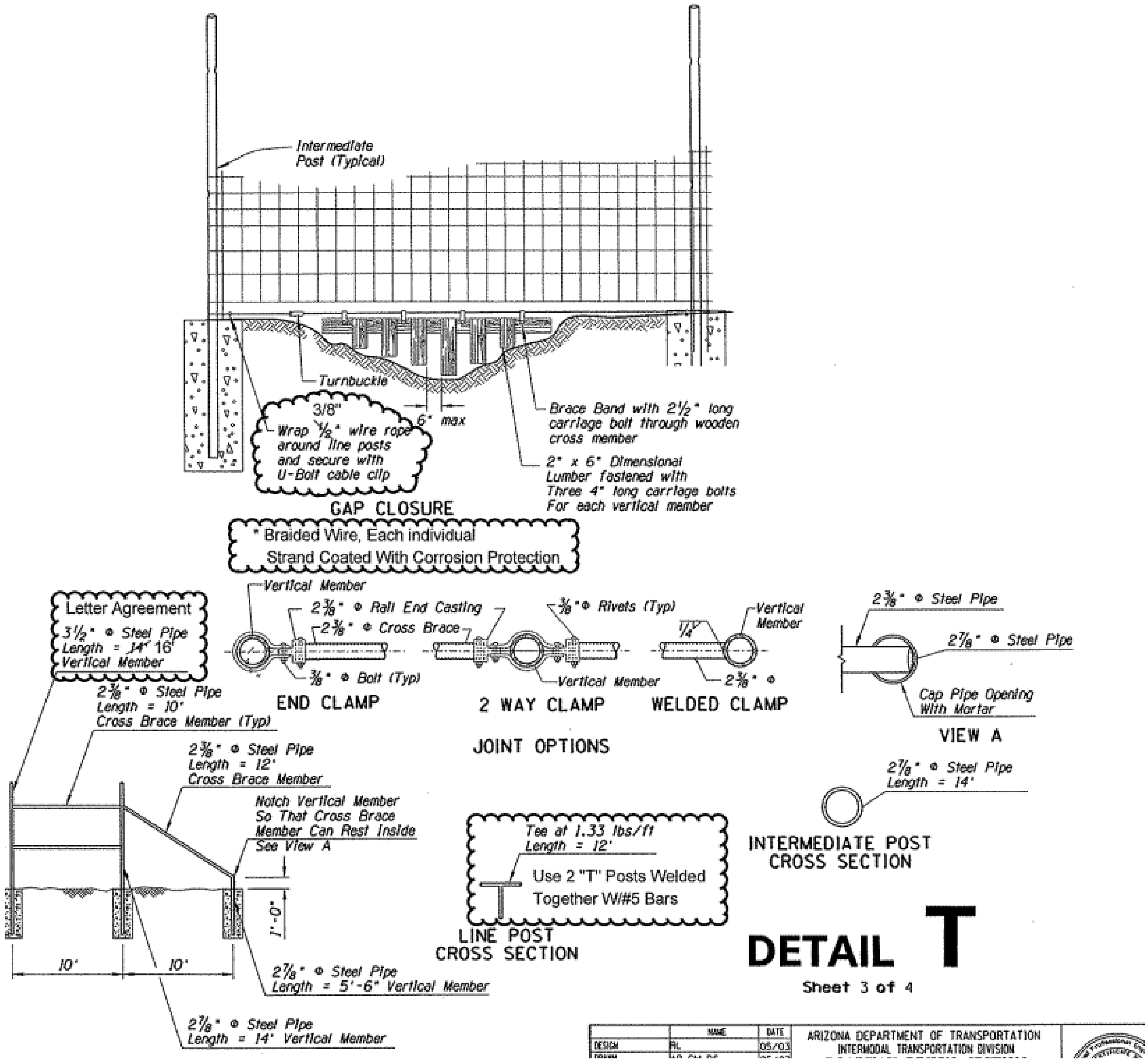


Figure 70. Detail of Fence Design for Spanning Uneven Topography

Wash Crossings

Given the association between wash crossings and burro-ROW access points, it is important to ensure that ADOT game fence specifications are maintained where ROW fence crosses washes while accounting for the challenges presented by hydrological flow. Several measures can be employed to minimize the risk of fence blowouts:

- Incorporate flood gate designs where ROW fence crosses a wash. Figure 71 represents a design that is currently under evaluation. In recurring problem areas, consider fence designs that can withstand hydrological flows either by using more robust materials or by incorporating hinged designs that can swing away under force rather than break. Ideally, such solutions would be set back from drainage structures and tied in with wildlife fence to support wildlife connectivity goals while excluding burros.
- Install one of the mitigations described in the ROW Fence Design section where fences traverse dramatic topographical changes.

Figure 71. Swinging Gate Design to Prevent Burro Passage But Allow Hydrological Flows

Crossing Guards

While standard crossing guards were effective in preventing burro-ROW entry within the study area, it is advisable to implement upgrades and periodic maintenance, particularly where BVCs are a recurring problem. Additional recommendations follow:

- Install crossing guards at unguarded driveways associated with BVCs.
- Use round bars instead of flat bars or use a grate material instead of bars (Gagnon et al. 2020).

- Install wing fencing along the edge of crossing guards to minimize the possibility of cross-jumps (Gagnon et al. 2020) (Figure 72).
- Tie in ROW fence and wing fence within crossing guard vaults to prevent burros from traversing vault ledges (Gagnon et al. 2020) (Figure 73).
- Add angle iron along the vault ledge or use rubber bumpers to reduce access to the vault ledge (Gagnon et al. 2020).
- Clear crossing guard vaults before sedimentation levels reach 50 percent depth.
- Survey crossing guard sedimentation levels annually.

Figure 72. Wing Fence at a Crossing Guard Tie-In

Figure 73. Chain-Link Wing Fence Tied in Within Crossing Guard Vault

Gate Designs

Gate dimensions are recommended to match the physical characteristics of ADOT game fence described in the ROW Fence Design section and to withstand the level of use at a given location.

- Install ADOT type 1 single or double gates (Figure 74) according to ADOT fence detail specifications at all gate locations in burro habitat.
- Use ADOT type 2 ranch-style gates only in low-traffic locations where they are already in place (Figure 75). Type 2 gates can be difficult to close or easily damaged and become unusable.
- Fully tie in ROW fence to all gates.
- Block apertures greater than 18 inches in height to prevent burro passage in nonstandard gate designs with apertures.
- Install monitoring devices to detect unclosed gates to improve response times. Increased enforcement presence or installation of real or mock cameras that monitor gates may also increase gate closing compliance.
- Consider installing informative signage or crossing guards where gates are consistently left open. AGFD has successfully worked with ADOT to develop and install informative signs in areas with wildlife exclusionary fences along SR 260 and I-17 (Figure 76).

Figure 74. ADOT Type 1 Double Gate

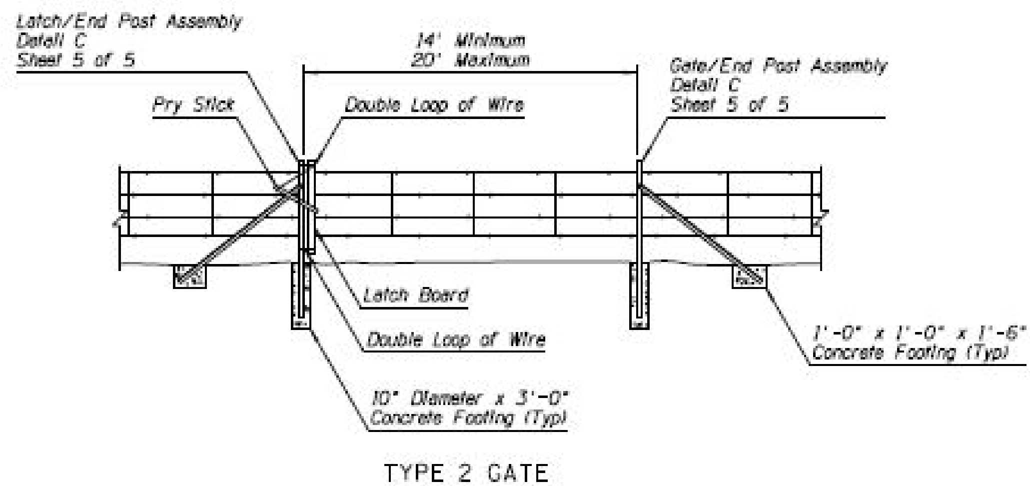


Figure 75. Type 2 Ranch-Style Gate Standard Drawing

Figure 76. Sign to Reduce the Incidence of Unclosed Gates

ROW Fence to Structure Tie-Ins

- Ensure all tie-ins meet ADOT game fence specifications with no horizontal gaps exceeding 6 inches between the fence terminus and structure.

Fence Ends

To mitigate end run effects where fences terminate abruptly without tying in to other barriers or structures:

- Extend the ROW fence to tie in to existing ROW fence, structures, or barriers, wherever feasible.
- If extending the ROW fence is not possible and fences end abruptly, consider the following:
    - Install seasonal signage warning motorists of potential burro crossings during BVC peak periods (October through January).
    - Reduce speed limits with enforcement.
    - Clear vegetation on both sides of the highway to increase visibility.

- Partially extend the fence into rugged or impassable terrain.
- Develop at-grade crossings with ungulate-activated detection systems and alert signage.

Preventing Trespass

Trespass through ROW fence onto adjacent lands is a recurring problem in the Lake Pleasant area, creating ROW access points that facilitate burro-ROW entry.

- At locations where trespassing is persistent, engage with agencies and landowners to increase accessibility to surrounding lands.
- If the land is available for public use, consider creating new guarded access driveways in problem areas.
- Where fence is being cut to facilitate trespassing onto private or closed lands, explore options to open access to these areas.
- If trespassers are circumventing locked gates, consider unlocking them where possible to promote human use at locations where burro access can be addressed by closing gates or adding crossing guards versus repairing cut fence.
- Develop updated fence details to incorporate cut-prevention measures. ROW fence can be reinforced by incorporating heavy gauge cables. The City of Tucson Water's fence standard with cut prevention cables (Appendix B) could be adapted to match the dimensions of ADOT game fence.
- Flank problem gates with short sections of cut-resistant chain-link fence (Figure 77).
- Install vehicle barriers, Jersey barriers, cable barriers, boulders, or vegetation barriers in front of or behind ROW fence to reduce vehicle accessibility.

Figure 77. Gate Modified with Signage, a Crossing Guard, Wing Fence Tied in Within the Vault Ledge, and Spans of Chain-Link Flanking Fence on Both Sides of Driveway to Deter Trespassing

Fence Surveys and Maintenance

- Conduct ROW fence surveys annually at a minimum and more regularly if possible.
- Schedule surveys shortly before annual peaks in BVCs (in late September or early October for the Lake Pleasant area).
- In areas around washes, schedule supplemental surveys after heavy precipitation or hydrological flow events.
- In heavily vegetated areas, schedule supplemental surveys after storm or wind events.
- In areas where fence is regularly cut, schedule supplemental surveys after periods of peak recreational use.
- Focus attention on crossing guards, gates, washes, dramatic topography changes, areas with nearby OHV trails, historic BVC problem areas, and fence-to-structure tie-ins.
- Complete fence maintenance as soon as possible after issues are detected.
- Ensure that any nonstandard additions that may have been lost are incorporated into new fence repairs.

BURRO-HIGHWAY CROSSINGS

At-grade highway crossings present a substantial BVC risk, whereas below-grade crossings can facilitate safe burro movement within HMAs but allow burros to access areas outside of HMAs.

- Prevent at-grade burro-highway crossings wherever possible:
  - Repair existing ROW fence or install new ROW fence (the most effective means of preventing at-grade highway crossings).
  - Where fence installation options are limited, consider installing warning signage (Figure 78), reducing speed limits, or increasing visibility by clearing vegetation from either side of the highway. Static warning signs, however, have shown inconclusive results for reducing wildlife-vehicle collisions due to motorist complacency over time, which may be the case for burros (Found and Boyce 2011; Rytwinski et al. 2016). Seasonal warning signs have shown more promise for wildlife and could work for burros if targeting seasonal movement and collision peaks from October through January (Sullivan et al. 2004; Hardy et al. 2006; Donaldson and Kweon 2019).
  - At at-grade crossings, in rugged terrain, and within areas of high human disturbance, consider terminating fence with detection systems and/or alert signage (Figure 79) or adding wildlife guards at the ends of the fence. Previous studies have shown that these strategies can reduce the number of ungulates entering the ROW, which may translate to similar outcomes for burros (Huijser et al. 2008; Gagnon et al. 2015; Siemers et al. 2015; Gagnon et al. 2019).
- Address issues at below-grade highway crossings, which allow burros to access areas outside of an HMA:
  - Consider strategies designed to restrict burro populations to within HMAs (see Burro Population Management section).
  - Consider installing fence solutions at a setback from structures to facilitate wildlife movement.
  - Ensure that fence details for installation across below-grade structures accommodate hydrological flow events (as described in the Fence and Barrier Installation and Maintenance section) without restricting wildlife movement.
- Only prioritize fence ends where complete ROW fencing is not an option.

Figure 78. Burro Warning Signage

Figure 79. Elk Crossing Alert Signage Triggered by a Detection System at an Elk Crosswalk

BURRO-ROW ENTRY AND COLLISION REPORTING

- Establish the BuRRITo app as the standard burro-ROW incident reporting tool. Distribute the tool to all responding agencies to use when reporting burro-ROW incidents within Arizona and provide trainings for field users.
- Develop live dashboards for local maintenance units to provide overviews of burro-ROW incidents by district.

INTERAGENCY COORDINATION

The following recommendations are made with the intent to facilitate and enhance interagency coordination:

- Establish additional IABTs (or similar stakeholder working groups in areas where BVCs are a concern) that engage with AGFD. IABTs bring together specialist knowledge from engineers, maintenance staff, biologists, range managers, law enforcement officers, and city planners to facilitate discussions that enable rapid development and implementation of mitigations to address the needs of each stakeholder. Since the initial IABT was established in 2013, there has been a concerted, collaborative effort between partner agencies and local jurisdictions to understand and mitigate BVCs in the Lake Pleasant area. Increased communication between stakeholders through regular meetings has helped to identify locations with high BVC potential.
- Maintain quarterly meetings of stakeholder working groups to address developing BVC concerns and refine mitigation methods with lessons learned.
- Continue to engage and incorporate stakeholders into IABTs as land ownership, jurisdiction, and BVC risk changes over time.

FURTHER RESEARCH

To expand knowledge of burro behaviors and BVC patterns and to provide greater scope for BVC mitigation, several topics were identified for further research.

Recreational Use Patterns

Documenting seasonal variations in recreational use within the Lake Pleasant area would provide valuable context for patterns of burro-ROW entry through vandalized ROW fence or unclosed gates. Results could help develop fence survey and maintenance schedules and enable seasonally targeted upticks in enforcement efforts.

BVC Demography and Regional Level Assessments

Using the BuRRiTo mobile application as a standardized tool for capturing burro-highway interaction data collection would allow analysis of BVC burro mortalities against overall population demographics.

This could provide valuable context for burros susceptible to BVC and present novel opportunities for preventive mitigation. An expanded BuRRiTo application to include state and regional level assessments would allow for a more general BVC analysis.

Historical Data Deficiencies

At the outset of the research project, no comprehensive database existed for BVCs within the study area, and the format of BVC data varied considerably between data sets. These inconsistencies limited the level of analysis that could be conducted for this study. For example, analysis of burro mortality demographics was limited by lack of sex and age class data, while fine-scale temporal patterns in BVCs could not be assessed due to inconsistencies in the documentation of time-related data elements. Historical reporting was primarily focused on collisions and burro mortalities, while burro-ROW entries that did not result in collisions or mortalities were largely absent from the data set. The increased level of detail and consistency of records collected through the BuRRITo app would allow investigation of these additional factors in the future.

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APPENDIX A: BURRO ROADWAY REPORTING INTERAGENCY TOOL (BuRRITo)

As a deliverable in the SPR-753 project, researchers developed the Burro Roadway Reporting Interagency Tool (BuRRITo), an interagency application for documenting burro incursions into ADOT, City of Phoenix, and City of Peoria transportation ROW near LPHMA. This tool provided a centralized and consistent method for recording and reporting burro detections along these roadways.

The initial platform was Esri's map-based Collector for ArcGIS (Collector) application developed for data collection via mobile devices. AGFD has used this platform to standardize and improve data collection for various efforts, including wildlife road mortality, dispersed camping sites, and nondesignated target shooting locales.

While developing the Collector tool, researchers learned of an alternative Esri platform—Survey123 for ArcGIS (Survey123), which is part of the same Esri ArcGIS Online suite of tools as Collector but is form-based instead of map-based. The form-based format allows for greater interface flexibility and provides a more streamlined and simplified data entry process for users. The simplified interface translates to a higher potential for use across a workforce that includes law enforcement officers, maintenance technicians, biologists, and others with varied levels of technological experience.

A draft burro incident application tool was developed for both Collector and Survey123 platforms and presented to representatives from BLM, AGFD, ADOT, Arizona State Land Department, and the City of Peoria at IABT meetings and to the BLM's Phoenix District Office GIS specialist, who were trained to use both applications. These representatives provided feedback on formatting and design revisions, and selected the Survey123 tool for use in this study. A final version of the tool was completed November 8, 2017.

The application allows users to enter the following information:

- **Agency affiliation**: Offers a list of 10 partner agencies and a "Not listed" option, which prompts a text field to enter the unlisted agency.
- **Username**: Autocomplete format generates a self-refining list of usernames associated with the agency identified in the previous field based on the letter combination entered into the username textbox.
- **Survey date and time**: Automatically populates the date and time that the record was initiated. The record can be edited as needed.
- **Observation type**: Offers options such as "live," "dead," or "sign" of burro presence. Any combination can be selected.
- **Within vehicle ROW** (only appears if "live" or "dead" is checked in previous field): Offers "yes" or "no" response option.

- **Burro count**: Requests the number of live adults and juveniles or dead adults and juveniles.
- **Interaction with wildlife documented**: Offers “yes” or “no” response option.
- **Type of sign** (only appears if “sign” is checked in **Observation type**): Requests a description of the sign (for example, scat/fecal, tracks, or damage).
- **Sign confidence level** (only appears if “sign” is checked in **Observation type**): Offers a response range on a “low” to “certain” scale.
- **Photo**: Requires user to enter a photo from the device camera app or device photo library.
- **Location**: Automatically populates with device location when the record is initiated. The record can be edited as needed.
- **Comments**: Offers an open text field for miscellaneous information.

APPENDIX B: CITY OF TUCSON WATER (COT WATER) FENCE SPECIFICATIONS

5 strand barbed and barbless wire fence specifications for COT Water. The fence will be 5' tall with a top and bottom strand of barbless wire and the three middle strands 4pt. barbed wire. There will also be two strands of 3/8" cable attached to the bottom strand of 4pt. barbed wire and the top strand of 4pt. barbed wire.

1. All materials supplied for these projects will be, " Made in America, USA".
2. TERMINAL POSTS: 2-7/8" OD galvanized Sch. 40 pipe set in a 12" Diameter by 48" deep 2500psi concrete foundation. The terminals will be NO more than 600' apart. Weld a steel ball cap to the top of the posts.
3. DOWN BRACES: 1-5/8" OD galvanized Sch. 40 pipe, (3 per terminal post), weld braces to the terminal posts 10" down from the top of the post and angle them at a 45 degree angle into the ground and set them in a 18"x18" 2500psi concrete foundation. Weld a 4"x4" galvanized plate on one end of each brace that is set in the concrete footer.
4. T-POSTS: 7' long 1.33 SR-T posts pounded 2' into the ground, and spaced no more than 10' apart.
5. BARBLESS WIRE: The top and bottom strands of wire will be barbless wire, two 12-1/2GA. Wires twisted together, Tie the barbless wire to T-posts with 9GA. Steel tie wires.
6. BARBED WIRE: The three middle strands will be 4pt. barbed wire, 12-1/2GA. With "S" barb spacings. Tie the barbed wire to the T-posts with 9GA. Steel tie wires.
7. CABLE: Install 2 strands of galvanized 3/8" cable onto the top and bottom strands of 4pt. barbed wire. Hog ring the cable to the barbed wire with 9GA. Hog rings, 4 per 10' section. Stretch the cable between each terminal post and wrap the cable around 12" to itself and use 3 "C" clamps per loop and tack the weld nuts after tightening them.
8. STAYS: Install 2-48" long 9-1/2GA fence stays per 10' fence section between the T-posts.
9. GATES: 20'x4' double drive gates. 1-7/8" OD galvanized Sch. 40 pipe gate frames all welded construction, three horizontal rails with 4 strands of 4pt. barbed wire stretched on them. Industrial 180 degree hinges. Weld two 6" pieces of ¼" chain to each gate leaf so that they can be chained in the middle. Weld all gate hinges.
10. GATE POSTS: 4" OD galvanized Sch. 40 pipe set in 18"x48" 2500psi concrete foundations. Weld a 4" ball cap at the top on each post.