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Wildlife-Vehicle Collision Mitigation on State Route 260: Mogollon Rim to Show Low

Arizona Department of Transportation Research Center

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16. Abstract

Wildlife-vehicle collisions (WVC) account for 32 percent of all collisions along State Route (SR) 260 above the Mogollon Rim (Rim). To facilitate projected traffic volumes and improve design standards from Overgaard to U.S. Route 60, the Arizona Department of Transportation first initiated a Location/Design Concept Report (L/DCR). This research study then was initiated to inform and adjust preliminary solutions to address WVC and maintain habitat connectivity along SR 260 from the Rim to Show Low (mileposts 280-340). The primary objectives were to evaluate elk and deer movements along SR 260 and spatial and temporal WVC patterns, before then recommending locations for wildlife crossing structures. The research team used GPS and WVC data and additional factors to identify 18 priority one mile segments for consideration of wildlife crossings. The team also made recommendations for right-of-way wildlife-exclusion fencing, wildlife crossings, escape ramps, lateral access roads, and maintenance considerations.

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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, ABBREVIATIONS, AND SYMBOLS

AADT	average annual daily traffic
ADOT	Arizona Department of Transportation
AGFD	Arizona Game and Fish Department
ASNF	Apache-Sitgreaves National Forests
CI	Confidence Interval
CMP	corrugated metal pipes
df	degrees of freedom
DPS	Department of Public Safety
EA	Environmental Assessment
EIS	Environmental Impact Statement
EVC	elk-vehicle collisions
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration
GIS	geographic information system
GPS	Global Positioning System
H	Kruskall-Wallis (test)
I	Interstate
K-S	Kolmogorov-Smirnoff (test)
L/DCR	Location/Design Concept Report
MCP	Minimum Convex Polygon
MP	milepost
OP	Wildlife Overpass
PWCM	preliminary wildlife crossing matrix
RCBC	reinforced concrete box culvert
RIM	Mogollon Rim

ROW	right-of-way
SA	Study Area
SDI	Shannon Diversity Indices
SE	standard error
SOW	Scope of Work
SR	State Route
TAC	technical advisory committee
TDMS	Transportation Data Management System
U	Mann-Whitney U (test)
UP	Wildlife Underpass
U.S.	U.S. Route
USFS	United States Forest Service
WCS	wildlife crossing structures
WVC	wildlife-vehicle collision

EXECUTIVE SUMMARY

Wildlife-vehicle collisions (WVC) cause injuries to motorists and significant property damage. State Route (SR) 260 exhibits one of the highest concentrations in Arizona of vehicle collisions with elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*). To address WVC concerns, among other issues, the Arizona Department of Transportation (ADOT) began planning for an upgrade of SR 260 from Overgaard (milepost [MP] 309.4) to U.S. Route (U.S.) 60 in Show Low (MP 340.1), (ADOT 2014). ADOT commissioned a Location/Design Concept Report (L/DCR), which indicated that from 2004 through 2008 32 percent of all collisions along SR 260 were with wild game (ADOT 2014). This was more than seven times the WVC national average of 4.6 percent (Huijser et al. 2007).

To identify possible solutions to reduce these collisions while maintaining wildlife habitat connectivity, ADOT requested that the Arizona Game and Fish Department (AGFD) join a Wildlife Connectivity Technical Advisory Committee (TAC) that also included Apache-Sitgreaves National Forests (ASNF). This multi-agency TAC compiled a list of 16 possible locations for wildlife-crossing structures (WCS) based on historic WVC data, topography, existing drainage structures (roadways bridges and culverts), and land ownership; and then they narrowed the list to nine preliminary locations based on cost, feasibility, and WCS spacing and decided that a site-specific elk and deer movement study would be prudent to determine which locations would be the most effective at reducing WVC via wildlife underpass crossings and also maintaining habitat connectivity. Since the study to be conducted was adjacent to the SR 260 segment west of Overgaard, an area that received minimal WVC provisions in a 2000 Environmental Impact Statement (EIS), the Wildlife Connectivity TAC chose to include the area within the study.

In order to develop data-driven recommendations in this study, the researchers applied established methods developed and verified on previous, long-term Arizona roadway studies that involved WVC and habitat connectivity. In addition to making recommendations, the study provides baseline roadway wildlife permeability data that verifies the post-construction efficacy of implemented mitigation measures while advancing the understanding of roadway, traffic, and wildlife interactions. The AGFD researchers specific objectives included:

- Assess elk and deer movement patterns and distribution along SR 260 and identify high-frequency crossing zones.
- Assess elk and deer roadway permeability and movements, and relation to traffic volumes.
- Investigate spatial and temporal WVC patterns and relationships to traffic volumes.
- Develop WCS locations recommendations (using existing structure retrofitting and new construction) and other WVC reducing mitigation measures that maintain or promote roadway permeability along SR 260 from MP 280 – 340.

Adjacent to SR 260 (2012-2015), the research team outfitted 60 elk and 15 deer with Global Positioning System (GPS) collars and monitored each animal's movements. The GPS collars collected relocations every two hours for a total of 415,416 elk relocations and 138,310 deer relocations. Of these relocations, 35 percent (elk) and 51 percent (deer) occurred within 0.62 mi (1000 m) of SR 260. Elk and deer crossed SR 260 (MP 280 – 340) 4094 and 646 times, respectively, and predominantly crossed in undeveloped areas. Overall, if an elk or deer approached SR 260, it successfully crossed the roadway 53 percent (elk) and 42 percent (deer) of the time. Regardless of month, day of week, and time of day, elk that approached the roadway were more likely than deer to cross the road.

As expected, passage rates of elk and deer (percentage of road approaches that resulted in road crossings) decreased as traffic volumes increased. In addition, elk and deer distributions shifted away from the roadway as traffic volume increased. Most notably, if elk or deer were within 0.37 mi (600 m) of SR 260, only 2 or 3 percent would venture closer—within 0.06 mi (100 m).

From 2005-2015, the research team evaluated 2509 vehicular collisions from MP 280-340; 798 of them (32 percent) involved wildlife (those were coded "Animal_Wild_Game" by the Arizona Department of Public Safety in crash reports). The percentage of SR 260 vehicular collisions that involve wildlife was approximately seven times the national average (4.6 percent). Of these WVCs, 384 and 414 happened west and east of Overgaard, respectively. As expected, WVCs did not occur randomly across the study area, but instead in defined general areas where mitigation efforts should be directed.

RECOMMENDATIONS

To delineate effective WCS locations, the research team rated 60 one-mile SR 260 roadway segments. The research team based the segment ratings on elk and deer roadway crossing locations, WVC locations, topography, land ownership, human activity, and appropriate spacing. The research team recommends that ADOT consider a total of 18 locations for WCS along SR 260: eight west of Overgaard to the Rim, and 10 east of Overgaard, from Overgaard to Show Low. These WCS would require a combination of new structures and retrofitting of existing drainage structures.

Of the 10 locations east of Overgaard, two are suggested for construction of wildlife OPs, along with an alternative site for a possible third OP. Three of the recommended locations involve existing roadway structures (the bridges at Cottonwood Wash, Mortensen Wash, and Pierce Wash) that could function as dual-use wildlife/drainage structures. As a short-term strategy to reduce WVCs, ADOT could continue to "retrofit" such existing drainage structures. This strategy was successfully implemented on I-17 for elk (Gagnon et al. 2015).

Part of this strategy is considering wildlife crossings and fencing as long-term solutions to mitigating WVCs and wildlife habitat fragmentation. This would mean linking WCS with 8 ft exclusion (ungulate-proof) fence to direct wildlife to viable crossings under the roadway. These measures have proven to reduce WVCs while maintaining habitat connectivity regardless of traffic volumes.

The team recommended such exclusion fencing for a majority of the study area outside of Heber, Overgaard, and Show Low. The research team advises against the use of several shorter unconnected fencing segments that would result in more wildlife ROW access opportunities. Fencing should terminate at logical locations: existing structures, cliffs, and straight road segments that allow motorists greater visual distance.

For the SR 260 section between Overgaard and Show Low, the recommendation is to install continuous fencing from Overgaard's Columbia Lane east to approximately Linden Wash at MP 333.6. This fence passes through most high WVC segments and wildlife road crossings, and if the fence were extended to Fool Hollow Wash (MP 338.95), the remaining, lower WVC segment near Bagnal Wash (MP 337.5) would be included.

For the section of SR 260 between the Rim and Overgaard, the recommendation is to install continuous exclusion fencing from the Mogollon Rim (west of the scenic overlook) east to the Black Canyon Bridge's western abutments near Heber.

Fencing should tie into or go up and around drainage culverts; thus, allowing smaller wildlife species to cross under the roadway and reduce fence maintenance costs related to water velocity and debris buildup. In addition to fencing, installing escape ramps (6 ft high) spaced approximately every half mi would allow egress for elk and deer trapped in the ROW, and installing double cattle guards, gates, or other design features at lateral access roads would limit elk and deer ROW access at those points.

CHAPTER 1: INTRODUCTION

PROBLEM AND RESEARCH JUSTIFICATION

During the past decade, transportation projects have increased that integrate properly designed wildlife crossing structures (WCS) to reduce wildlife-vehicle collisions (WVCs) and promote wildlife passage under or over roadways (Forman et al. 2003). The WCS studied have made roadways more permeable for a variety of species (Foster and Humphrey 1995, Gagnon et al. 2011, Dodd et al. 2012a, Van Manen et al. 2012, Clevenger and Barrueto 2014, Sawyer et al. 2016), have allowed those species to avoid inbreeding and extirpation by permitting genetic interchange (Corlatti et al. 2009), and in conjunction with exclusion fencing, have significantly reduced WVCs (Clevenger et al. 2001, Olsson and Widen 2008, Gagnon et al. 2010, Dodd et al. 2012a).

To maximize wildlife use of properly designed WCS, design and location are vital considerations (Reed et al. 1975, Foster and Humphrey 1995, Clevenger and Waltho 2000;2005, Dodd et al. 2007d, Bissonette and Adair 2008, Gagnon et al. 2011, Cramer 2013) as is the distance or spacing between those structures. Bissonette and Adair (2008) suggest that passage structure spacing be based on the isometric scaling of a species home range. Their suggested spacing was intended to help maintain landscape connectivity by providing crossing opportunities at intervals within distances that allow animals to encounter them as they move across the landscape. Dodd et al. (2012) found that passage structure spacing was inversely associated with elk permeability, which further supports the need for WCS at adequate intervals. This means that to effectively locate, place, and space WCS and erect exclusion fencing, designers should rely on species-specific movement, roadway crossing, and WVC data. This approach, while simultaneously promoting wildlife-roadway permeability and safety, was pioneered in Arizona on SR 260.

State Route 260 (SR 260) from the Mogollon Rim (Rim) escarpment to the town of Show Low has one of Arizona's highest concentrations of WVCs (Figure 1). These collisions involve the resident and migratory herds of elk and deer that occupy habitat along the Rim portion of SR 260 east of Payson. The human and wildlife safety concerns stemming from these collisions were considered when ADOT conducted a Final Environmental Impact Statement (FEIS) that included the area between Payson (MP 251.94) and Heber (MP 303.74) and focused on upgrading and realigning sections of SR 260 to a safer four-lane divided roadway (FHWA 2000). In 2000, ADOT began to reconstruct a 17 mi SR 260 segment east of Payson and below the Rim. This segment was divided into five sections (Preacher Canyon, Little Green Valley, Kohl's Ranch, Doubtful Canyon, and Christopher Creek) and the sections with the highest WVC rates were reconstructed first (Dodd et al. 2007a). When the entire 17-mi segment had been reconstructed, it included 11 wildlife underpasses (UPs) and six large bridges that were suitable for wildlife use. In addition to the UPs and bridges, exclusion fencing connected the structures to the right-of-way, prevented elk from crossing SR 260 at grade, and redirected them to the structures. At locations where the fencing crossed lateral access roads, ADOT placed doublewide cattle guards to limit elk ROW access and placed in-line fence escape ramps throughout the project to permit animals that did enter the ROW to have egress (Dodd et al. 2012a). In all, this 17-mi segment of SR 260 has 17 WCS, more than 34 mi of exclusion fencing, a number of doublewide cattle guards, and numerous escape ramps.

Figure 1. Cow Elk Killed by a Vehicle Along SR 260 During the Study

Throughout and after the SR 260 reconstruction process, AGFD researchers received ADOT funding to research and evaluate the effectiveness of the mitigation measures (Dodd et al. 2007a, Dodd et al. 2012a). After nearly a decade of evaluation (pre-, during-, and post-reconstruction), research results have indicated that WCS and exclusionary fencing are effective at reducing WVCs and maintaining habitat connectivity. In part, the researchers documented a reduction in elk-vehicle collisions (EVCs) of greater than 85 percent and usage of select UPs by more than 10,000 animals. As a whole, elk and deer were able to safely cross the newly constructed, wider SR 260 (Dodd et al. 2007a, Dodd et al. 2007b;c, Dodd et al. 2007d, Gagnon et al. 2007b, Gagnon et al. 2007c, Gagnon et al. 2010, Dodd and Gagnon 2011, Dodd et al. 2012a).

Although SR 260 WVCs below the Rim had been effectively addressed, WVCs above the Rim were still a concern (Figure 2 and 3). Above the Rim, the number of WVC per year increased relatively linearly from around 40 WVC per year in 2002 to around 80 per year in 2012 (Figure 3). Over that same 10-year period, WVC percentage increased in a curvilinear manner from 19 percent in 2002 of all incidents coded with Animal_Wild_Game in crash reports by the Arizona Department of Public Safety (DPS) to 45 percent in 2012 (Figure 3), far exceeding the national average of 4.6 percent (Huijser et al. 2007). In 2009, to address safety concerns and anticipated traffic volume increases, ADOT began planning for the reconstruction of SR 260 from Overgaard (MP 309.4) to U.S. 60 in Show Low (MP 340.1; ADOT 2014). During the process, ADOT partnered with the Arizona Game and Fish Department (AGFD) and the Apache-Sitgreaves National Forests (ASNF) to determine roadway mitigation solutions that would reduce WVCs and maintain habitat connectivity. Their discussions led to this joint research project by AGFD and ADOT to collect and synthesize information to determine possible, effective mitigation measures; AGFD was funded by ADOT and received supplemental funding from the Wildlife and

Sportfish Restoration Program of the US Fish and Wildlife Services. The research project would involve gathering, analyzing, and synthesizing data related to local elk and deer movements, traffic volumes, WVCs, topography, existing structures, and other information that could be used to inform the planning effort, the ongoing Environmental Assessment (EA), and the Location/Design Concept Report (L/DCR).

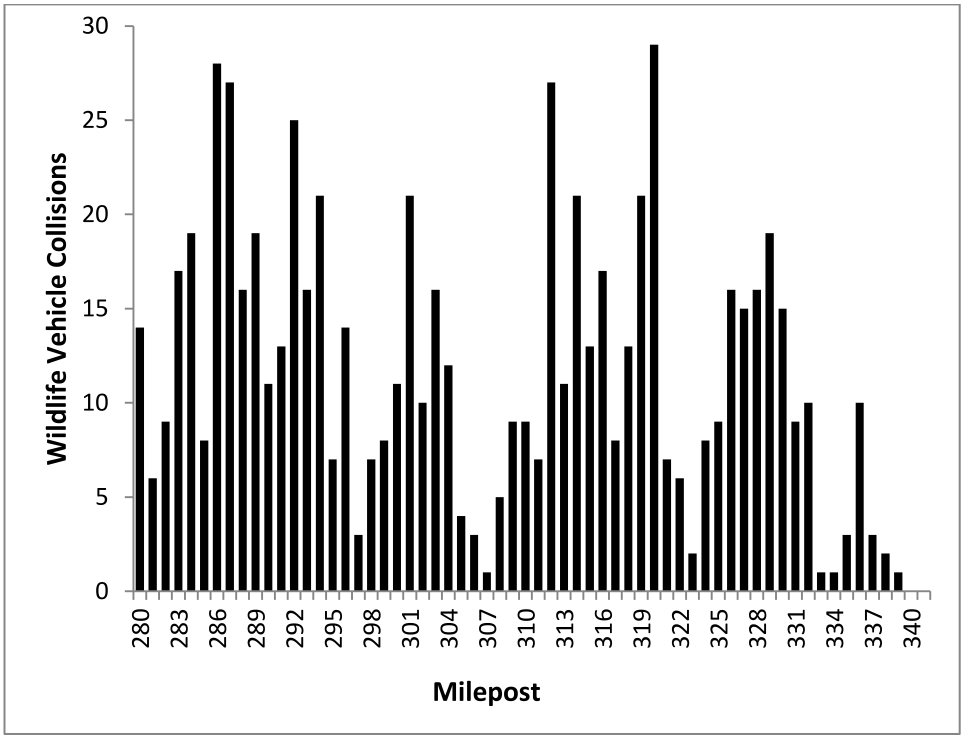


Figure 2. Wildlife-Vehicle Collisions by MP from the Mogollon Rim (MP 280) to Show Low (MP 340) from 2002-2012 (ADOT TDMS)

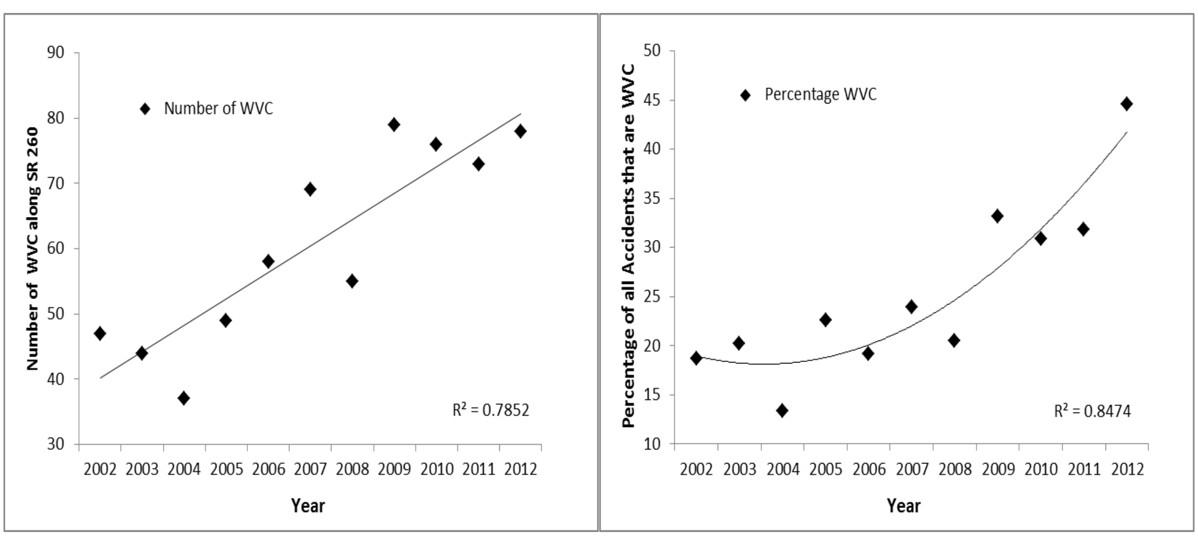


Figure 3. Number of Wildlife-Vehicle Collisions (WVC, Left) and Percentage of All Crashes Involving Wildlife (Right) on SR 260 (MP 280 – 340) from 2002-2012 (ADOT Traffic Records Report)

This study's overall objectives were to gather, analyze, and synthesize site-specific data in order to develop WVC reduction recommendations that denote the location, placement, and spacing of possible retrofitted and newly constructed WCS, exclusion fencing, and additional mitigations. The specific study activities included the following:

- Assess SR 260 elk and deer movement patterns and distribution and identify high-frequency crossing zone locations.
- Assess elk and deer roadway permeability, movements, and determine how they relate to traffic volumes.
- Investigate spatial and temporal WVC patterns and relationships to traffic volumes.

CHAPTER 2: STUDY AREA

The research team conducted this study along 60.1 mi of SR 260 from MP 280 at the Rim eastward to MP 340.1 in Show Low (lat 34° 18’ 1.91’N - 34° 14’ 30.2” - long -110° 54’ 18.2” - 110° 3’ 31.5”). SR 260 is a rural principal arterial roadway that functions as the primary connection between the greater Phoenix metropolitan area and the White Mountains and links Payson to northeastern Arizona and New Mexico. The roadway is traveled yearly by more than 2 million vehicles. SR 260 through the study area (SA) exists as it was originally constructed in the 1950s and 1960s (SR 160)—a two-lane, undivided roadway; however, some passing and turning lanes have been added and the roadway near Show Low (MP 338.1 – 340.0) was improved in 1998 to an urban five-lane road.

WESTERN AND EASTERN STUDY AREAS

The research team divided the SA into two primary segments: Rim to Overgaard (MP 280 – 309) and Overgaard to Show Low (MP 309 – 340.1, [Figure 4]). Each segment varies in WVC rates, traffic volume, topography, and reconstruction planning phase. At the time of this study, ADOT did not have reconstruction plans for the Rim to Overgaard segment of SR 260; however, the segment may be reconstructed in the future and was included in a 2000 FEIS (FHWA 2000). Since the 2000 FEIS had inadequate WVC provisions, ADOT and its partners thought it prudent to include the segment within the study’s scope. The Overgaard to Show Low segment is further along in ADOT’s reconstruction planning process and was part of a L/DCR and EA (ADOT 2014). The L/DCR and EA for this segment serve as a reconstruction guide for the improvements needed to accommodate projected traffic volume increases and to maximize motorist’s safety. The final L/DCR includes appendices for AGFD preliminary wildlife roadway mitigation solutions—WCS and exclusion fencing locations (ADOT 2014). Since both segments differ in WVC rates, traffic volume, topography, and ADOT’s planning phase, the research team’s analysis, results and recommendations are reported for each segment.

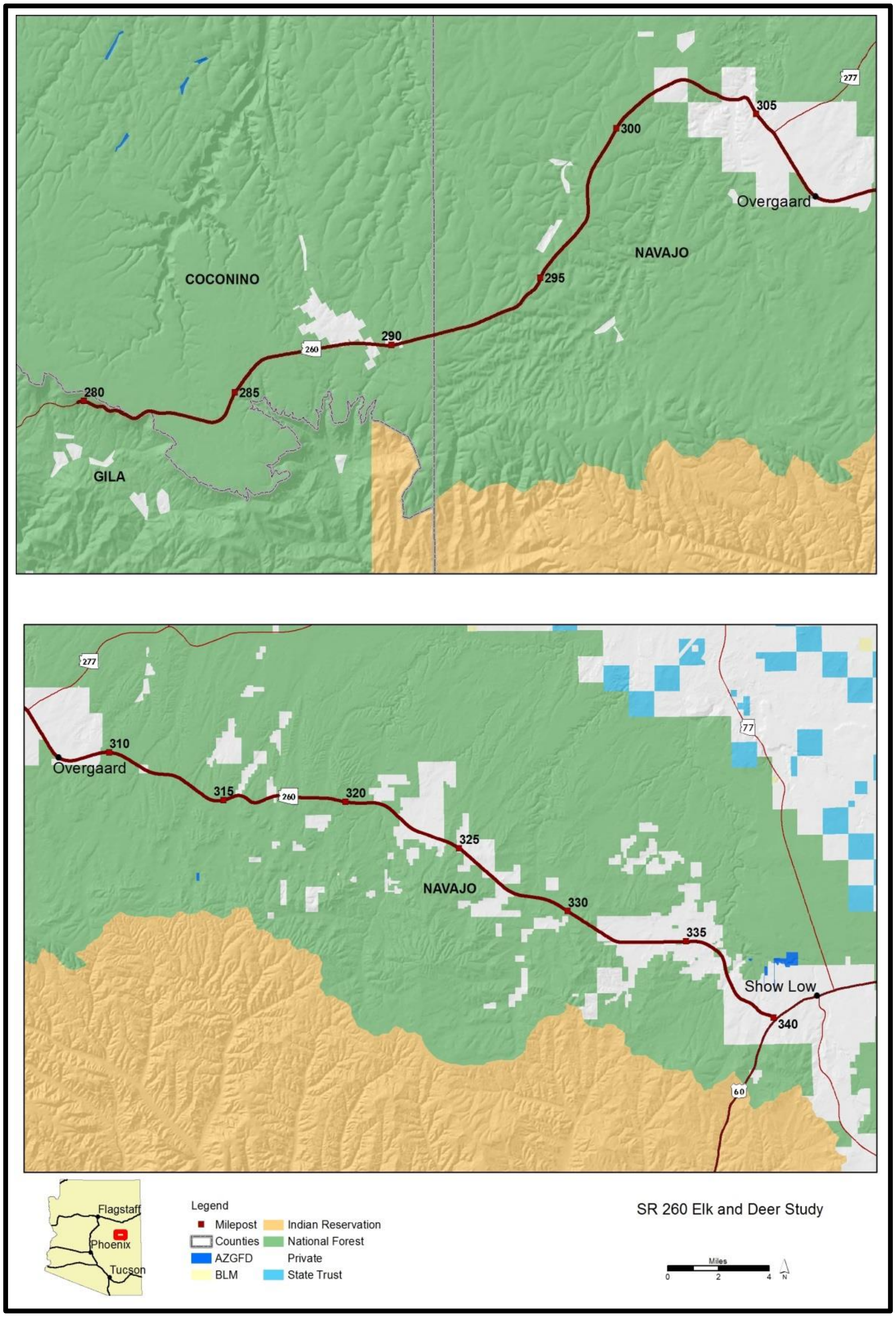


Figure 4. Study Segments: the Rim to Overgaard (Top) and Overgaard to Show Low (Bottom)

TRAFFIC CHARACTERISTICS

For the Rim to Overgaard SA (MP 280 – 309), there was not a functioning continuous traffic counter during the study; however, other area sampling counters allowed researchers to derive traffic count data for this area. The derived 2012 to 2015 Rim to Overgaard Average Annual Daily Traffic (AADT) volume was 6113 vehicles per day (Figure 5). This AADT is 2215 vehicles per day higher than that collected (Transportation Data Management System [TDMS] Counter Location ID 101519) for the Overgaard to Show Low (MP 309 to 340.1) SA for the same time period (Figure 5). Vehicular traffic west of Overgaard is likely higher because motorists use SR 260 to access SR 377 (2053 vehicle/day) to reach Interstate 40 (I-40) and destinations beyond. The SAs monthly, hourly, and daily traffic volumes exhibit similar patterns but volumes west of Overgaard were consistently higher (Figure 5). In summer, the time of year when many Phoenix area residents use SR 260 to access summer homes and recreational opportunities, traffic volumes peak—averaging approximately 300,000 (west SA) and 175,000 (east SA) vehicles in the month of July (Figure 5). During the study, February traffic volumes were the lowest with 123,268 and 72,035 at the west and east SAs, respectively. Traffic volumes on weekends was consistently higher than weekdays, particularly on Friday when daily traffic volumes averaged 8161 (west SA) and 4774 (east SA, [Figure 5]). Tuesdays had the lowest traffic volumes with 5534 (west SA) and 3328 (east SA, [Figure 5]). Hourly traffic volumes were highest during midday (10:00 to 15:00 MST) where volumes were generally 250 and 150 vehicles/hour along the west and east SA, respectively. Traffic volumes were very low from midnight to 04:00 MST and never exceeded 20 vehicles/hour on either SA (Figure 5).

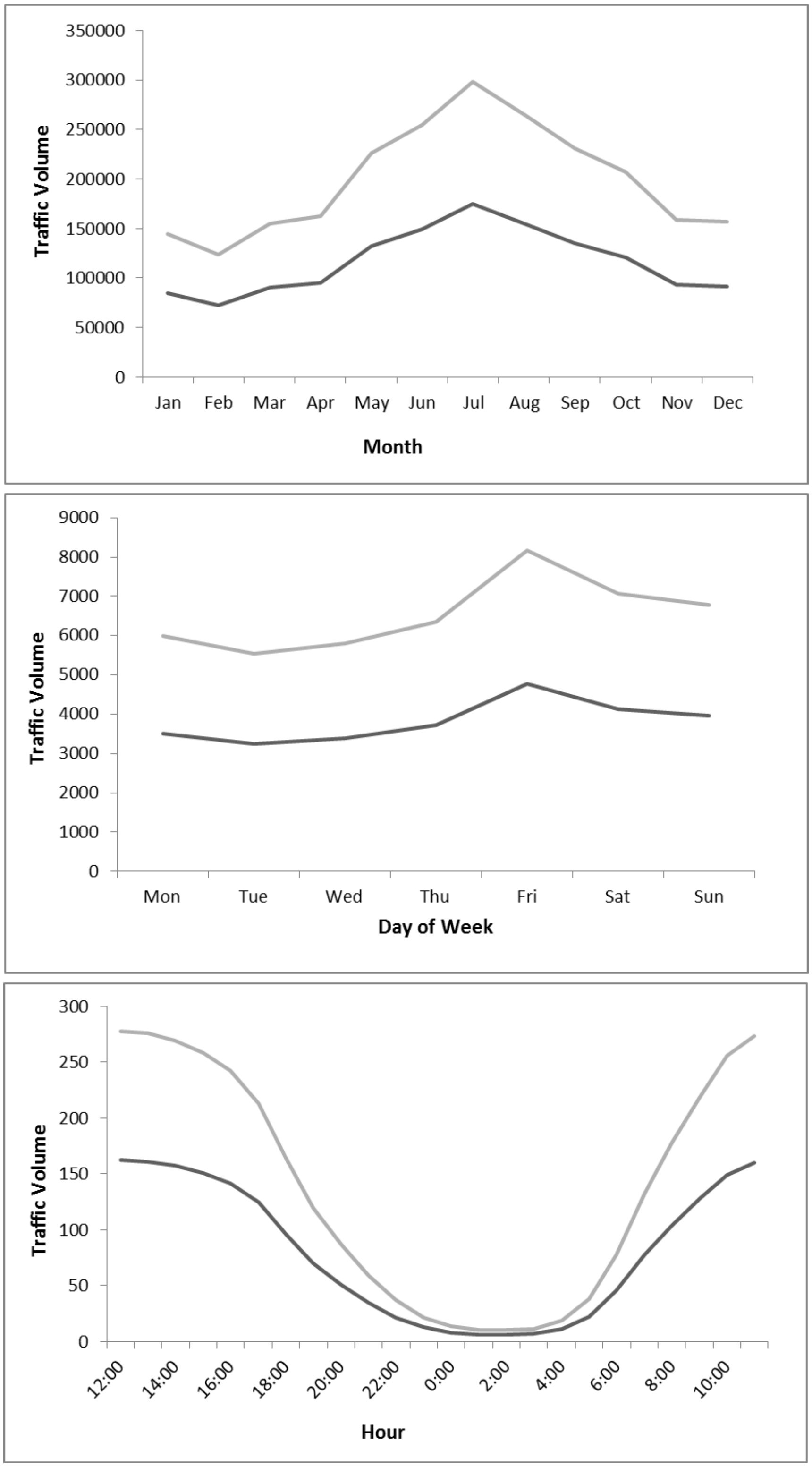


Figure 5. 2012-2015 Monthly, Daily, and Hourly Traffic Volumes for the Mogollon Rim to Overgaard (Grey Line) and Overgaard to Show Low (Black Line) Study Areas (ADOT TDMS)

LAND OWNERSHIP, NATURAL SETTING, AND CLIMATE

The SR 260 study site is located in east-central Arizona on the Rim, an escarpment at the southern limit of the Colorado Plateau and classified as montane (Spence et al. 1995). The elevation along the roadway varies from 7513 ft at the Rim to 6345 ft near Show Low. The topography ranges from flat to gently rolling and numerous drainages and ravines emanate from the north, intersect the roadway, and travel south to the Rim. Land ownership is primarily Federal (ASNF) with interspersed private land consisting of towns, small rural communities, and dispersed residences located along SR 260.

The climate is semi-arid, with hot summers, cool winters, and a strong bimodal precipitation pattern (summer monsoon rains and winter snows). Average annual precipitation is 15.8 inches, and average winter snowfall is 38.9 inches. July is the warmest month, with average highs of 85° F, and January the coolest, with average lows of 15.8° F.

Vegetation in the SA corridor exhibits characteristics of the Petran Montane Coniferous Forest and Great Basin Conifer Woodland biotic communities (Brown 1994, Spence et al. 1995). Ponderosa pine (*Pinus ponderosa)* and patchy Gambel oak (*Quercus gambelii*) dominate the Montane Coniferous Forests overstory along the western SA corridor (Figure 6) and rabbitbrush (*Ericameria nauseosa*) and cliffrose (*Cowania mexicana*) can be found in the understory. In addition, several wet meadow-riparian habitats are found adjacent to or near the western roadway corridor. This Montane Coniferous Forest vegetation provides summer range for elk and other wildlife. The eastern SA corridor, which is typical of Great Basin Conifer Woodland, has an overstory of ponderosa pine interspersed with sparse to dense pinyon pine (*Pinus edulis*), oneseed juniper (*Juniperus monosperma*), and Utah juniper (*Juniperus osteosperma*) and an understory of cliffrose, Apache plume (*Fallugia paradoxa*), other shrubs, and blue grama (*Bouteloua gracilis)* and other grasses covering the numerous, large open areas (Figure 6). The eastern vegetation community, depending on yearly snowfall, can serve as elk and deer summer and winter range.


Figure 6. Dense Ponderosa Pine Dominates the Western Study Area (Left) and the Eastern Study Area Is More Open (Right).

The SAs lie within the boundaries of the area burned by the 2002 Rodeo-Chediski wildfire (Figure 7), which burned with uneven intensity over 468,635 acres, leaving a mosaic of unburned, lightly burned, and severely burned areas (Kuenzi et al. 2008). The two study areas mimic that mosaic: the western SA (Rim to Overgaard) was unburned to the north of SR 260 and lightly burned to the south, while the eastern SA (Overgaard to Show Low) was burned on both sides of the roadway (Figure 7). Post-fire vegetation regeneration was prolific throughout these burned areas and the local elk and deer populations increased as a result.

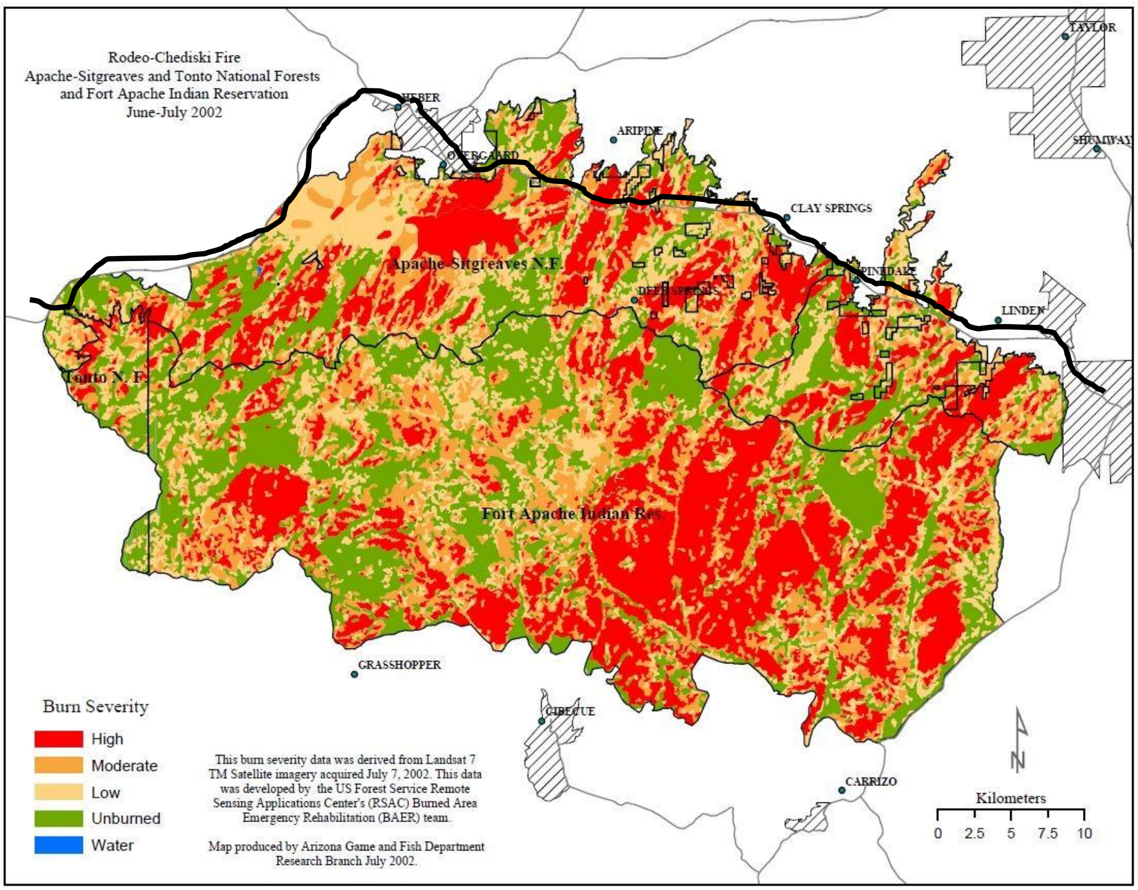


Figure 7. The Extent and Severity of the 2002 Rodeo-Chediski Wildfire that Increased Forage for Elk and Deer Along SR 260 (Thick Black Line) (Source: AGFD 2002)

ELK AND DEER POPULATIONS

The majority of SR 260 from the Rim to Show Low lies within good elk and deer habitat that supports relatively large populations of these animals. The area also has a history of frequent WVCs, which have significantly increased since the 2002 Rodeo-Chediski wildfire. Following the wildfire, vegetation regeneration provided elk and deer with an abundance of preferred food sources and population numbers responded. Elk were drawn to areas of high fire intensity (Bristow and Cunningham 2008). The elk population increased in large growth surges in 2009 and 2013 and has remained sizeable, averaging approximately 3000 animals for the past decade (AGFD unpublished data, [Figure 8]). To a greater extent, the post-fire mule deer population has dramatically increased—growing from 747 (2006) to 3784 (2015, AGFD unpublished data [Figure 8]).

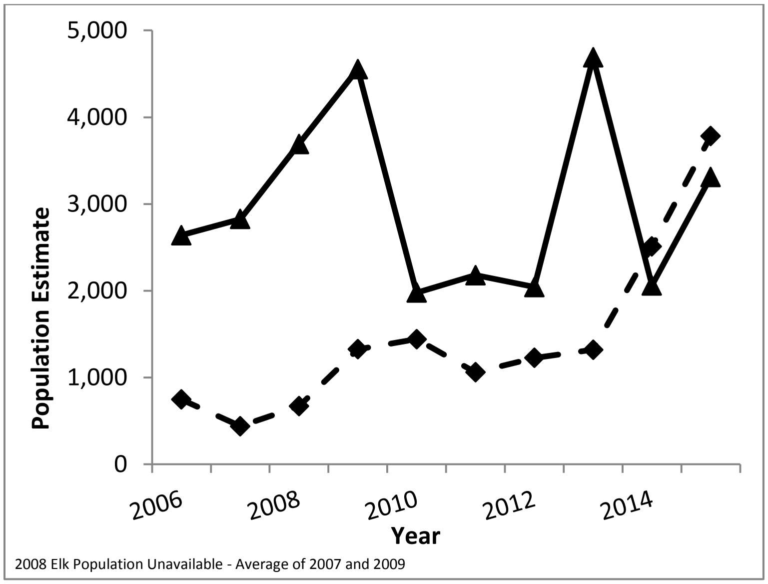


Figure 8. Estimated Populations of Elk (Solid Line) and Deer (Dashed Line) Along SR 260 from the Mogollon Rim to Show Low, 2006-2015 (Source: AGFD 2015)

CHAPTER 3: METHODOLOGY

ELK AND DEER HIGHWAY PERMEABILITY AND CROSSING DISTRIBUTION

The research team evaluated spatial and temporal elk and deer crossings by analyzing GPS data from elk and deer captured within the study areas (SA) and fitted with GPS collars. The team used modified Clover traps (Clover 1954) baited with salt and alfalfa hay to capture the majority of elk. Once captured, the team fitted elk with GPS collars and individually numbered ear tags and documented sex and approximate age (Figure 9). The elk were then released wearing GPS collars (Telonics Inc. Model TG3, TG4 store-on-board or Model SST-TG3 Spread Spectrum) that included VHF technology, a mortality sensor, release mechanism, and were programmed to receive one GPS relocation every two hours between 17:00 and 07:00 MST for 24 months. The research team utilized chemical immobilization administered via a projectile syringe or dart fired from a CO_2 projector or gun to capture some elk and all of the deer (Figure 10). To locate the animals during darting, the researchers drove a spotlight equipped vehicle along the SR 260 SAs between the hours of 22:00 and 05:00 MST when traffic volumes were low and animals were actively foraging near the roadway. The team blindfolded, ear tagged, and fitted GPS collars on all immobilized elk and deer (Figure 10) and administered reversal drugs when handling was complete. The research team remained near animals until they were able to leave the capture area.

Figure 9. Instrumenting an Elk with a GPS Collar (Left) and a Collared Elk Being Released from a Modified Clover Trap (Right)

Figure 10. Sighting in the CO_2 Projector or Gun (Left) that was Used to Chemically Immobilize Deer in Order to Instrument the Animal with a GPS Collar (Right)

After two years, the pre-programmed release mechanism allowed the collars to unfasten and drop to the ground. The research team then used VHF telemetry to locate and retrieve the dropped collars. The team downloaded all collar data and imported it into ArcGIS® Version 10.2 Geographic Information System (GIS) software (ESRI, Redlands, California) for analysis; this type of analysis has been used by the team on previous Arizona projects (Dodd et al. 2007a, Dodd et al. 2007b, Gagnon et al. 2010, Dodd et al. 2011;2012b, Gagnon et al. 2013a, Gagnon et al. 2014). The team calculated individual minimum convex polygon (MCP) home ranges by connecting the outermost GPS locations to encompass all locations (White and Garrott 1990).

The research team used an approach employed by Dodd et al. (2007a) and Gagnon et al. (2013, 2014) and divided the study area into 600 sequentially numbered 0.1 mi segments that correspond to ADOT's WVCs tracking and roadway maintenance units (Figure 11). For every elk and deer, the team calculated the number and proportion of GPS fixes within 0.15, 0.30, and 0.60 mi of SR 260. The team then connected each animal's consecutive GPS fixes and inferred roadway crossings where the lines between fixes intersected a SR 260 segment. The team then tallied crossings by 0.1 mi segments to determine peaks in crossing frequencies along SR 260.

For each roadway segment, the research team also calculated Shannon Diversity Indices (SDI), which accounts for the number of individual animals that crossed each SR 260 roadway segment and crossing frequency evenness among animals (Shannon and Weaver 1949). The use of SDI reduces the influence of an individual animal on the overall crossing results and places a higher weight on segments with crossings by multiple animals. These weighted segments more accurately reflect the approximate number of animals (collared and uncollared) that cross a particular road segment (Dodd et al. 2007b, Dodd et al. 2012b, Gagnon et al. 2013a). The research team calculated SDI for each segment using this formula:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Thus, to calculate SDI (or H') for each highway segment, the researchers calculated and summed all $p_i \ln p_i$ for each animal that had approaches in the segment, where each p_i is defined as the number of individual collared elk and deer crossings within each segment divided by the total number of respective crossings in the segment. The team used SDI to calculate weighted crossing estimates for each segment, multiplying uncorrected crossing frequency by SDI. These weighted highway crossings more accurately reflect the number of crossing and approaching animals, and equity in distribution among elk and deer (Dodd et al. 2007b, Dodd et al. 2012b, Gagnon et al. 2013a).

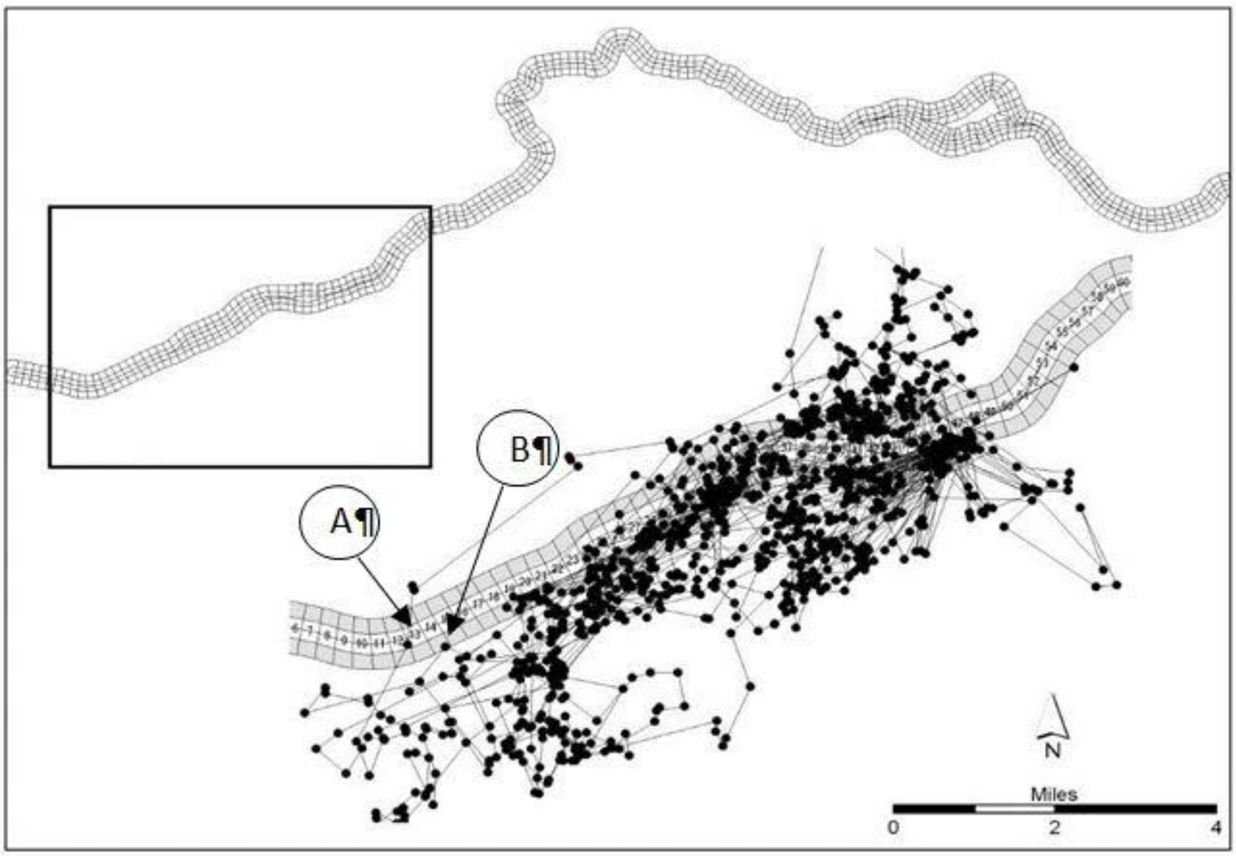


Figure 11. GPS Elk Locations and Lines Between Successive Fixes that Define Roadway Approaches and Crossings of a SR 260 Divided into 0.1mi Segments

(Note: The expanded section shows GPS locations of elk and lines between successive fixes to determine approaches to the highway [shaded band] and crossings. Example A denotes an elk approach and crossing; Example B denotes an approach without a crossing)

For collared elk and deer, the team calculated passage rates, which served as a relative measure of highway permeability and are directly comparable to other Arizona wildlife-highway projects (Dodd et al. 2007a). The team considered a roadway approach to have occurred when an animal's successive GPS relocations points indicated that it traveled from outside a 0.15mi SR 260 buffer zone to inside the zone (Figure 11). The approach zone corresponds to the road-effect zone associated with traffic-related disturbance (Rost and Bailey 1979, Forman and Deblinger 2000) and has been previously used along other Arizona highways for elk and deer by members of the research team (Dodd et al. 2007a, Dodd et al. 2007b, Gagnon et al. 2007b, Gagnon et al. 2010, Dodd et al. 2012a, Dodd et al. 2012b, Gagnon et al. 2013a, Gagnon et al. 2015). The team counted animals that directly crossed SR 260 from a point beyond 0.15 mi zone as an approach and a crossing. The research team calculated passage rates as the proportion of roadway crossings to approaches for those elk and deer that had at least five approaches.

The team compared crossing (crossings/day) and passage (approaches/crossings) rates at various temporal scales: time of day, day of the week, month, and season. For time of day, the team used the 2hr intervals that correspond to those of the GPS relocations schedule.

TRAFFIC VOLUME AND ELK AND DEER PERMEABILITY AND DISTRIBUTION

The research team measured traffic volume using a SR 260 ADOT Automatic Traffic Recorder programmed to record hourly traffic volumes. The research team compared traffic volume to elk and deer crossings and passage rates temporally: time of day, day of the week, and month. The team calculated the proportion of GPS relocations within specified distances from SR 260 as traffic volume varied (e.g. mean distances of elk and deer from SR 260 at 100 vehicles/hr versus 400 vehicles/hr) . These distances correspond to those defined by Gagnon et al. (2007a) and are consistent with other Arizona ungulate research (Gagnon et al. 2007b, Dodd and Gagnon 2011, Dodd et al. 2012b, Gagnon et al. 2013a). The research team combined traffic and GPS data by assigning traffic volumes for the previous hour to each GPS location using ArcGIS® Version 10.2 GIS (ESRI, Redlands, California) and Microsoft Excel. This allowed researchers to correlate the hourly traffic volume that each animal experienced with the movement it made to a particular distance of SR 260. The research team also evaluated the relationship between elk and deer passage rates and traffic volumes.

ELK AND DEER-VEHICLE COLLISIONS

For a consistent, long-term evaluation of WVC trends over time, the team used Department of Public Safety (DPS) vehicular collision reports, as collected by ADOT, to calculate WVC rates. DPS reports an "Animal Wild Game" incidence (their WVC term) when motorists are injured or there is significant property damage. DPS reports do not denote what wild game species are involved in crashes, however, within the SA the primary species large enough to cause injury and/or significant damage in a collision are deer and elk. The research team analyzed collisions by location according to MP and by year, month, and time of day to determine temporal and spatial WVC trends. Additionally, the team temporally and spatially assessed the proportion of WVCs to all crash types and compared the results to the national average. Lastly, the team compared the association of WVCs to traffic volume and wildlife populations.

IDENTIFICATION OF WILDLIFE CROSSING STRUCTURE SITES

Prior to the elk and deer movement study, the SR 260 Wildlife TAC utilized the best available information, including WVC data, current drainage and bridge structure spacing, and topography to identify preliminary WCS locations and prepared a WCS Matrix for the L/DCR. In the assessment of potential WCS sites and validation of the WCS Matrix, the research team considered the site selection criteria but also recognized that the 0.1mi segment scale was too small and cumbersome to discern and analyze differences among segments (Sawyer and Rudd 2005). Although, Dodd et al. (2007a) reported that the optimum scale to address management recommendations for accommodating wildlife passage needs using GPS telemetry or WVC data was the 0.6mi scale, the ADOT collected DPS collision data is better suited to a 1.0mi scale. Historically, DPS and ADOT typically used the nearest MP to mark WVC locations, a practice that creates artificial peaks in WVC at MP locations. To more accurately locate these WVCs, the research team used the MP as the mid-point for this analysis. For example, MP 290 encompasses MP 289.50 to MP 290.49. Because WVCs are tied directly to human safety, the research teams felt ratings for this study should also follow this format. Making recommendations at the 1.0 mi scale also provides ADOT engineers with latitude when determining the best, technical location for a WCS. Thus, the team converted the 600 – 0.1mi segments between MP 280.0 and MP 340.1 to sixty 1.0 mi segments for analysis.

The research team used, with some modifications, several of the criteria identified by Sawyer and Rudd (2005) to rate each 1.0 mi segments based on several factors: GPS crossing data, WVC incidence, human activity, suitable terrain for WCS, and land status or ownership. This criteria based rating has also been applied to SR 64 (Dodd et al. 2012b), U.S. 89 (Dodd et al. 2011), I-17 (Gagnon et al. 2013a), and I-40 (Gagnon et al. 2012).

The team applied the following criteria based rating scales:

Elk and deer highway crossings – The research team based this rating on the frequency of SR 260 crossings made by GPS collared elk and deer within each aggregated 1.0 mi segment and reflected the influence of existing land use patterns. The team weighted elk crossings higher than mule deer crossings because elk are a greater motorist safety concern. Ratings were:

Elk:

0	No crossings
1	1−10 elk crossings
3	11−30 elk crossings
5	31−50 elk crossings
7	51−70 elk crossings
9	71− 100 elk crossings
11	>100 elk crossings

Deer:

0 No crossings
1 1–30 deer crossings
3 31–60 deer crossings
5 >60 deer crossings

WVCs – The research team applied a weighted rating to this criterion due to the WVC impact on highway safety. The criterion uses 10 years (2006-2015) of "Animal_Wild_Game" traffic incidents recorded for each 1.0mi segment. The ratings were:

0 No WVC
1 1–5 WVC
3 6-10 WVC
6 11-15 WVC
9 16-20 WVC
12 >20 WVC

Human activity – Ideally, no human activity would occur near a WCS; however, road access, businesses, developments, and other activities do occur adjacent to SR 260. Ratings were:

0 Significant human activity (business, housing, etc.)
1 Moderate human activity (access roads)
3 Limited human activity
6 No human activity

Terrain – The ability to locate WCS using existing, navigable ridgelines, cut slopes, or drainages is cost effective and promotes structure use by wildlife. Ratings were:

0 Terrain not suited for a passage structure (steep, broken)
1 Terrain marginal for a passage structure (flat)
3 Terrain could accommodate a passage structure (small drainage)
6 Terrain ideally suited for passage structure (ridgeline or cut slopes for overpass (OP) and drainage for UP)

Land status – This criterion reflected the ability to conduct construction activities (e.g., using fill material to create an OP approach) outside the ADOT ROW. Ratings were:

1 Private
5 Federal – U.S. Forest Service ([USFS]multiple-use focus)

In addition to the above criteria, the research team considered other factors in its identification of potential WCS sites. These factors included 1) whether the 1.0 mi segments coincided with the preliminary SR 260 L/DCR recommended WCS sites, 2) what types of structures suited the site, and 3) how the priority segments from this study relate to the minimum recommended passage structure spacing determined by Bissonette and Adair (2008). Bissonette and Adair (2008) recommend WCS spacing of 1.1 and 2.2 mi for deer and elk, respectively. To reach a balance between ideal WCS spacing and potential fiscal constraints, the research team's goal was to place structures approximate 2-3 mi apart. Gagnon et al. (2010, 2015) and Dodd et al. (2012) showed that elk permeability is significantly lower when passage structures are spaced beyond these distances.

Once the research team rated each 1.0 mi segment, they determined the upper 99 percent confidence interval (CI) and used these segments as a baseline for determining WCS locations. For these locations, the team considered appropriate structure spacing and the location of existing structures that could serve as WCS. In addition, the team used the L/DCR recommendations to guide structure locations between Overgaard and Show Low. When a highly rated segment was adjacent to an L/DCR recommended segment or a suitable, existing structure, the team deferred to the adjacent segment. Once priority locations were identified, the team considered structure spacing throughout the study area before formulating final passage structure recommendations.

STATISTICAL ANALYSIS

Due to the non-normality of passage rate data, the research team utilized non-parametric statistical methods for comparison of results and determination of statistical significance (Cunningham et al. 1993). Tests included comparison of two pair Mann-Whitney U (U) tests and multiple comparison Kruskall-Wallis (H) tests. U tests and H tests are non-parametric versions of T-tests and Analysis of Variance (ANOVA) allowing for comparison of two or more samples from distributions that do not conform to normal distributions. The team used a Kolmogorov-Smirnoff (K-S) test to evaluate distribution of crossings. In this case the K-S test evaluates the probability that the crossing occurred randomly. Tests that resulted in P-values of less than 0.05 were determined significantly different. The team reported all means with ±1 standard error, for example a mean of 65 and a standard error (SE) of 2.3 is reported as 65 (±2.3).

CHAPTER 4: RESULTS

ELK AND DEER MOVEMENTS ALONG SR 260

Between December 2012 and July 2014, the research team captured 87 elk (73 females, 14 males) adjacent to SR 260 above the Rim and instrumented the animals with GPS receiver collars. The team was able to retrieve data from 60 of the collars (49 females, 11 males) and the other 27 experienced an unknown malfunction rendering data irretrievable. GPS collars were worn by elk for an average of 533.5 days (±27.9) and during that time the collars accrued 415,416 GPS locations (Figure 12) for a mean of 6699.2 locations/elk (±564.5). Of these locations, 191,212 locations (46 percent) within 0.6 miles (1000 m) of SR 260, 154,183 (37 percent) within 1000 m, 29,161 (7.0 percent) within 250 m, and 7868 (1.9 percent) within 100 m. Elk travelled an average of 823.5 ft (±41.27) between GPS locations with males traveling slightly farther (898 ft) than females (810 ft). Elk MCP home ranges averaged 849.5 mi^2 (±188.1). Mean male home ranges (1701.2 mi^2 ±623.4) differed significantly from mean female home ranges (662.1 ±177.2, K-W = 6.8, $P = 0.009$).

Between December 2012 and July 2014, the research team captured 17 mule deer (13 females, 4 males) adjacent to SR 260 above the Rim and instrumented them with GPS receiver collars. Of the collared deer, 15 (11 females and 4 males) yielded data sufficient to calculate roadway crossing, approaches, and passage rates. GPS collars were worn by deer for an average of 413.7 days (±59.4), during which time the collars accrued 138,310 GPS locations (Figure 13) for a mean of 8136 (±1324.4) per deer. There were 80,803 locations (58 percent) within 0.6 miles (1000 m) of SR 260, 70,582 (51.0 percent) within 1000 m, 6729 (9.7 percent) within 250 m, and 3492 (2.5 percent) within 100 m. Deer travelled an average of 1306.7 ft (±294.9) between GPS locations; with mean female deer (1348 ft) traveling further than male deer (1190 ft). Deer MCP home ranges averaged 35.9 mi^2 (±12.7). Mean male home ranges (39.1 mi^2 ±18.8) did not differ significantly from mean female home ranges (35.0 mi^2 ±15.9, K-W = 0.46, $P = 0.50$).

ELK AND DEER CROSSING DISTRIBUTION

Collared elk crossed the SR 260 4094 times, with a mean of 67.7 roadway crossings/elk (±14.3) and a range of 0 to 711 crossings/elk. Of the collared elk, five (8.0 percent) did not cross SR 260 and the other 55 elk crossed the roadway an average of 0.12 (±0.02) times/day. Crossing rates by females (0.14 crossings/day ±0.02) were significantly higher than males (0.02 crossings/day ±0.01, $U = 12.6$, $P < 0.001$), which equates to females crossing the road an average of every 7 days and males crossing every 50 days.

Elk crossed the highway in a non-random distribution (K-S = 14.05, $P < 0.001$), crossings each 0.1 mi segment 6.7 (±0.55) times with a range of 0 to 177 crossings in a given segment. Elk crossed SR 260 between the Rim and Overgaard 2637 times (9.05 [±1.05] crossings/segment) and crossed the roadway between Overgaard and Show Low 1425 times (4.58 [±0.40] crossings/segment, $U = 15.11$, $P < 0.001$).

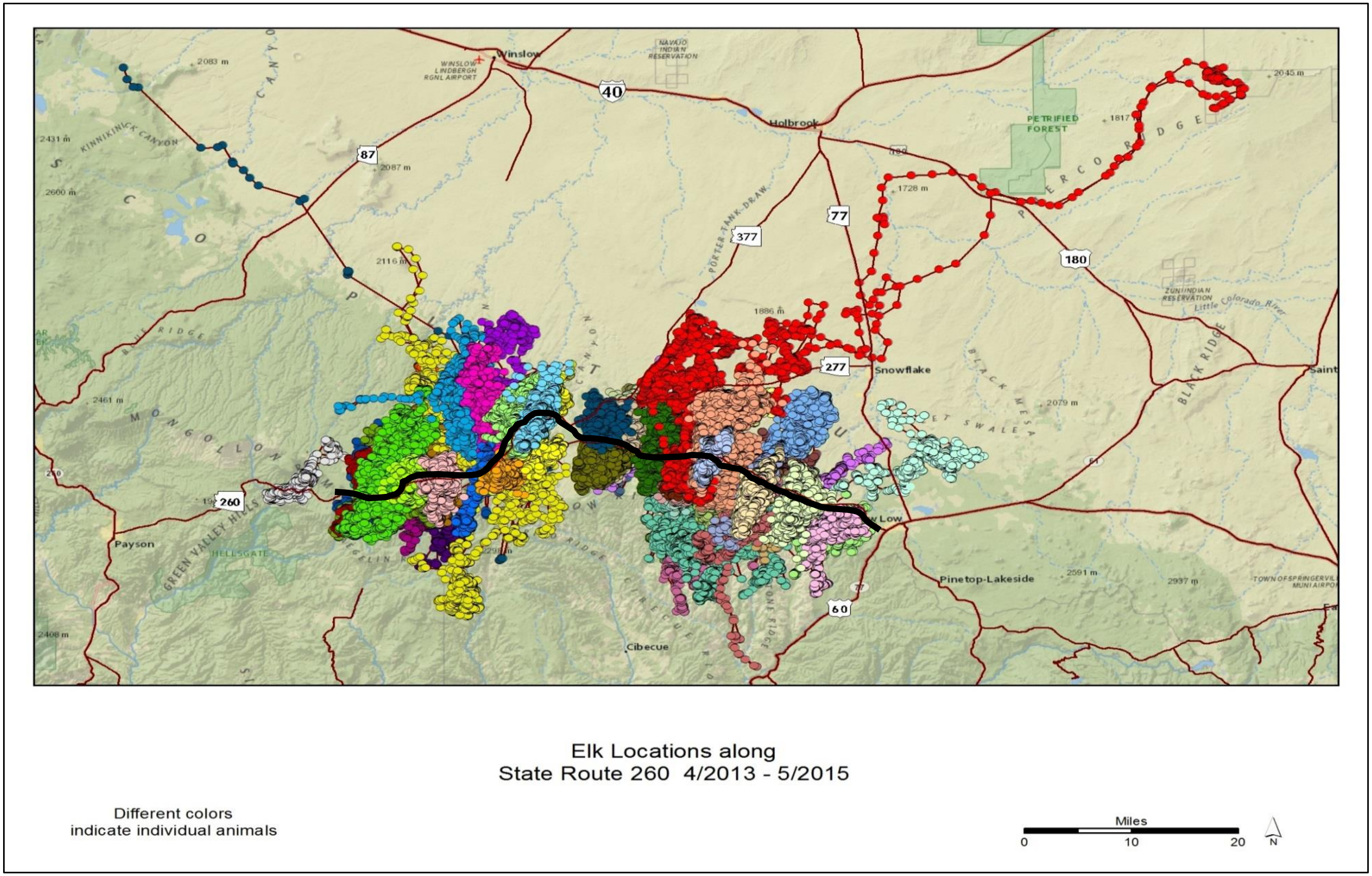


Figure 12. GPS Data Collected from 60 Collared Elk Along SR 260 (Thick Black Line) During the Study

(Each color represents an individual elk, and each dot a location taken every two hrs from 17:00 to 7:00 MST)

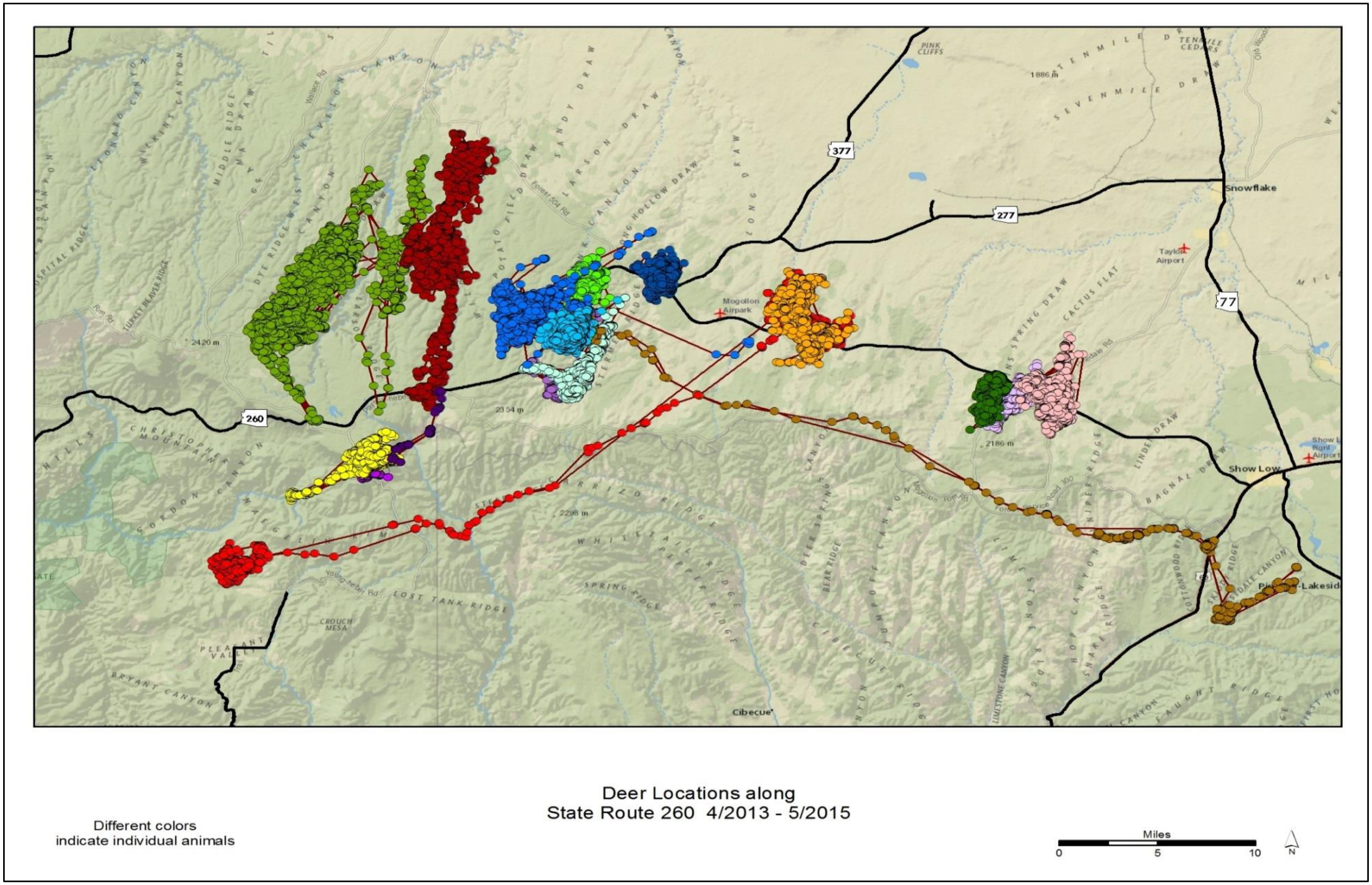


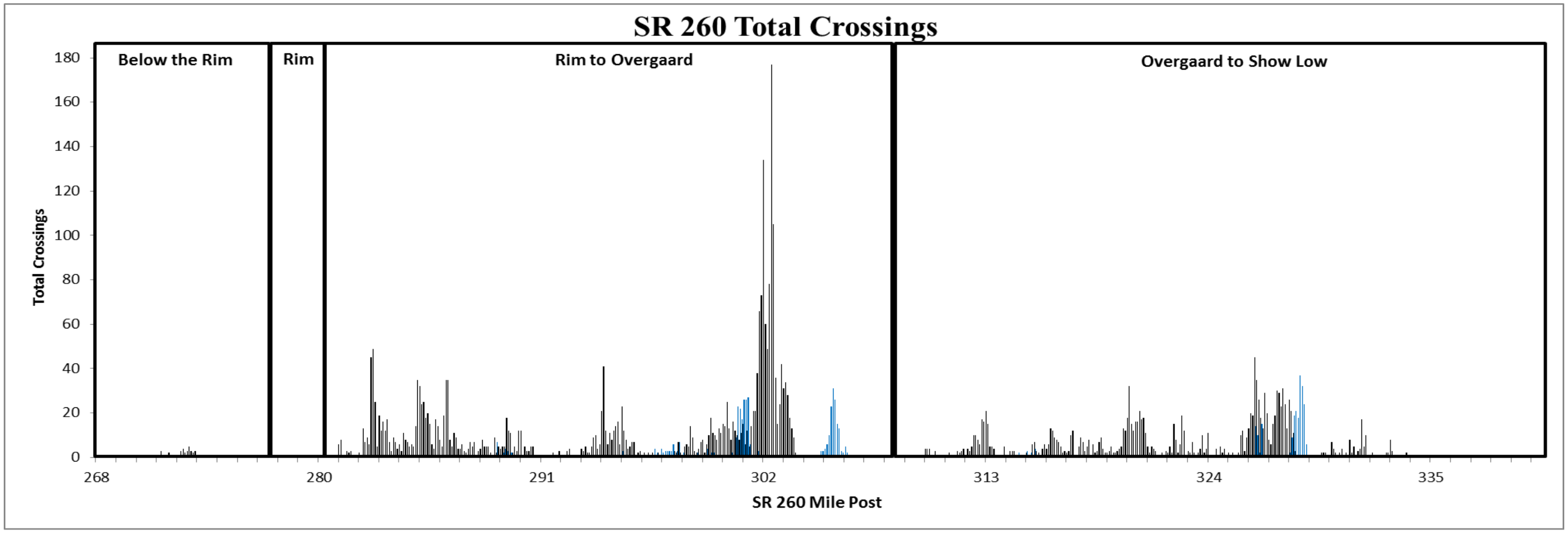
Figure 13. GPS Data Collected from 15 Collared Mule Deer Along SR 260 During the Study

(Each color represents an individual deer, and each dot a location taken every 2 hrs from 17:00 to 7:00 MST)

Weighted elk crossings ranged from 0 to 128.76 (mean = 6.08 [±0.39]). Overall, crossing peaks for actual and SDI weighted crossings were similar and indicates that the actual elk crossings were representative of elk populations movements (Figure 14). Elk roadway crossings occurred most frequently in areas east and west of Overgaard that had minimal human development (Figures 15 and 16). The SDI weighting accentuated roadway segments where numerous, individual elk crossed and deemphasized segments where an individual elk crossed numerous times (Figure 17 and 18).

Collared deer crossed the roadway 646 times, with a mean of 42.53 roadway crossings/deer (±17.4) and a range of 0 to 172 crossings/deer. Of the collared deer, two (13.3 percent) did not cross SR 260 and 13 crossed an average of 0.10 (±0.04) times/day. Female crossing rates (0.13 crossings/day ±0.05) were not significantly higher than males (0.04 crossings/day ±0.02, U = 0.28, P = 0.60), which equates to females crossing the road an average of every 10 days and males crossing every 25 days.

Mule deer also crossed the highway in a non-random distribution (K-S = 15.95, P < 0.001), crossings at each 0.1 mi segment 61.6 (±017) times with a range of 0 to 37 crossings in a given segment. Deer crossed the stretch of road from Rim to Overgaard 408 times (1.40 [±0.27] crossings/segment) versus nearly half of that for the area from Overgaard to Show Low (238 crossings, 0.76 [±5.11] crossings/segment, U = 20.45, P < 0.001). Deer roadway crossings occurred most frequently in areas east and west of Overgaard that had minimal human development (Figures 19). The SDI weighting identified a few roadway segments where numerous, individual deer crossed—MP 295 – 296 (Figure 20 and 21) being frequently used—however, due to the low number of deer included in this study, additional areas were not identified.



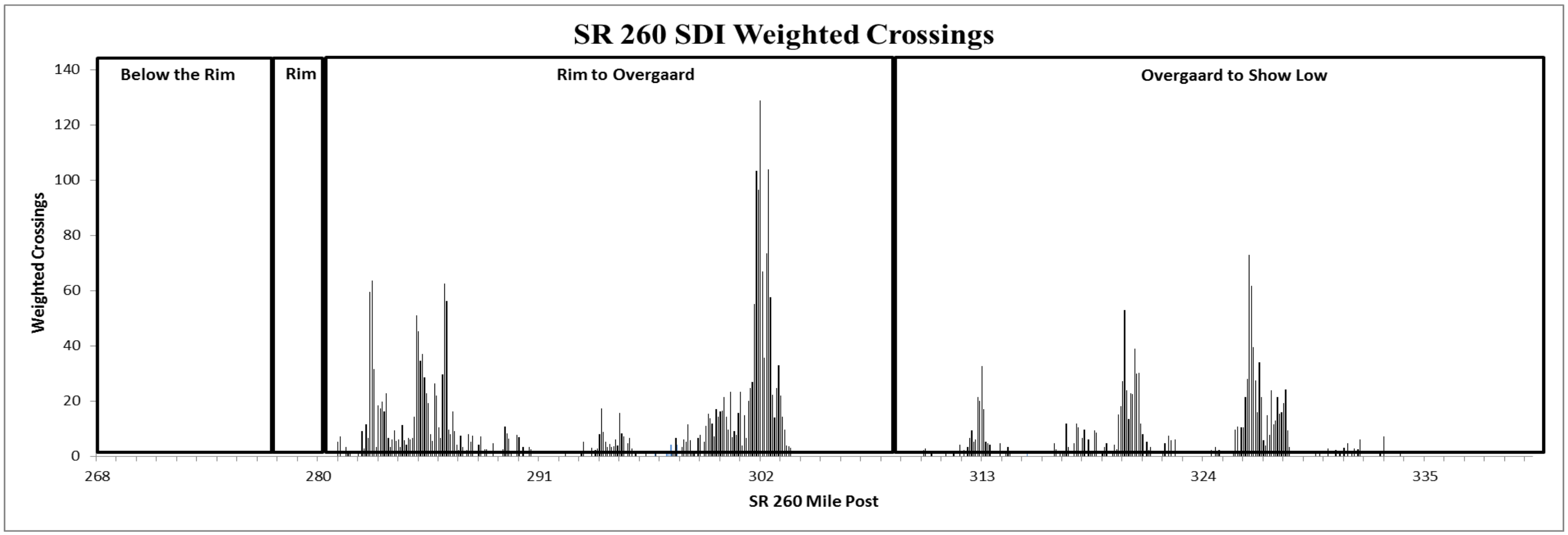


Figure 14. Total and Weighted Elk (Black Bars) and Mule Deer (Blue Bars) Crossings Along SR 260

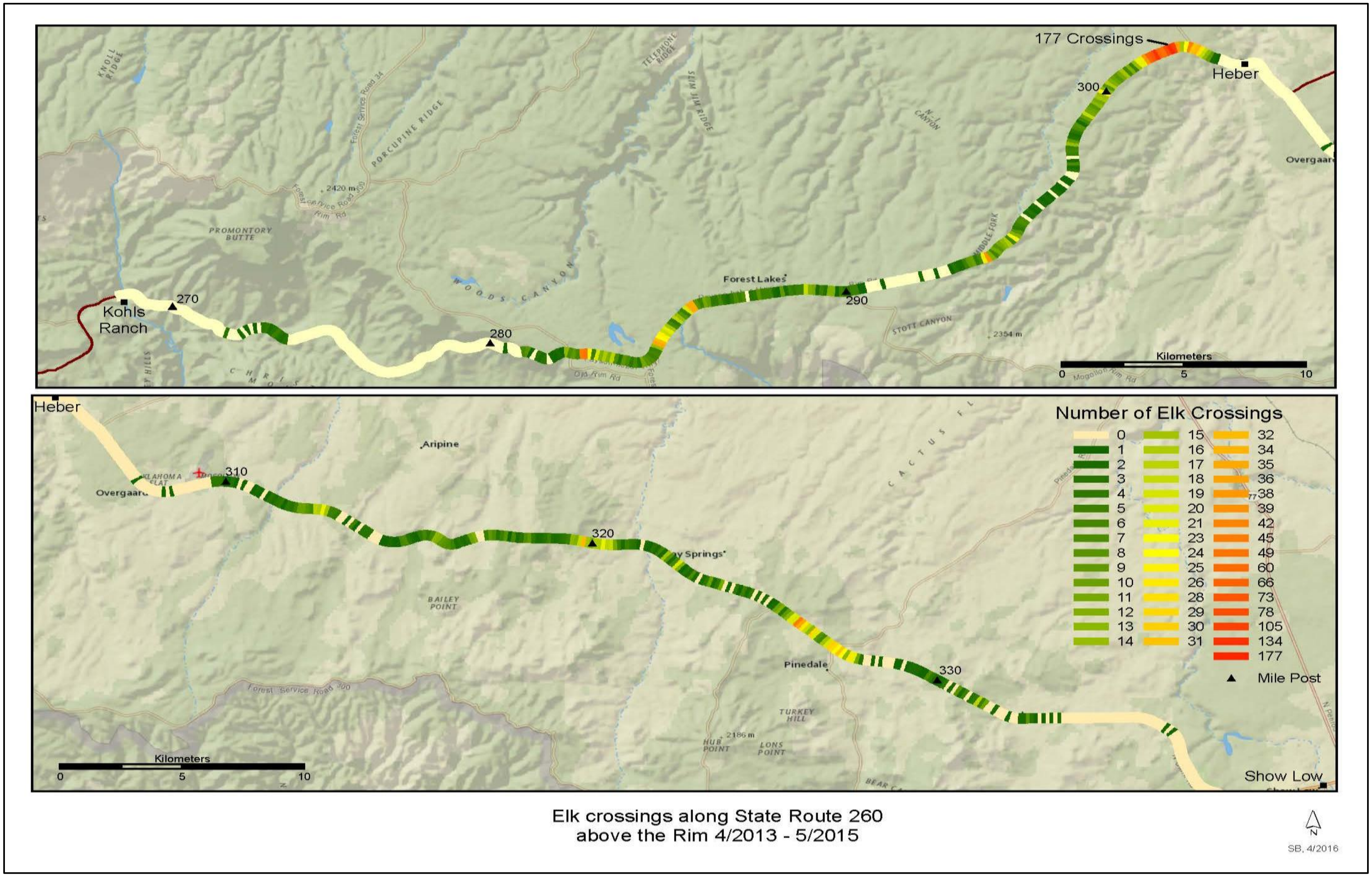


Figure 15. GPS Determined Crossings by 0.1 mi SR 260 Segments from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom). GPS Data Retrieved from 60 Collared Elk

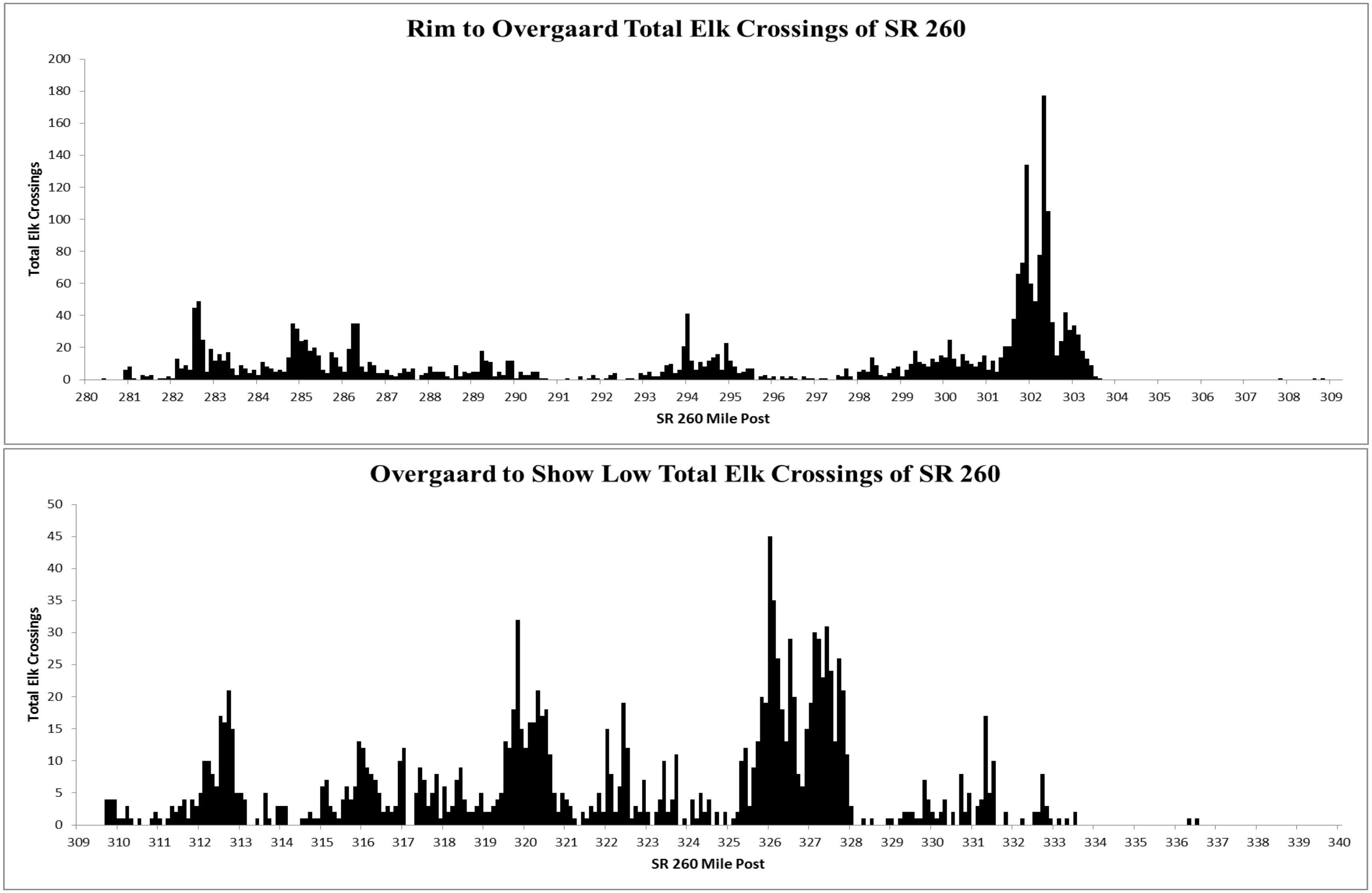
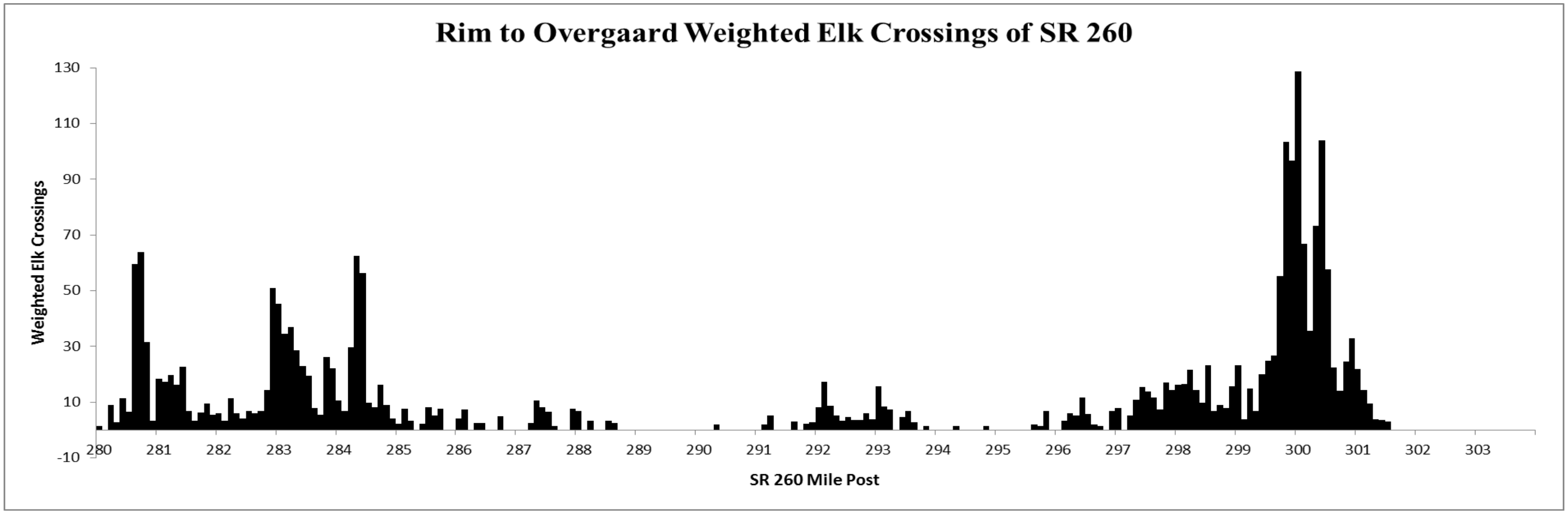


Figure 16. Total Elk Crossings by Milepost from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom)



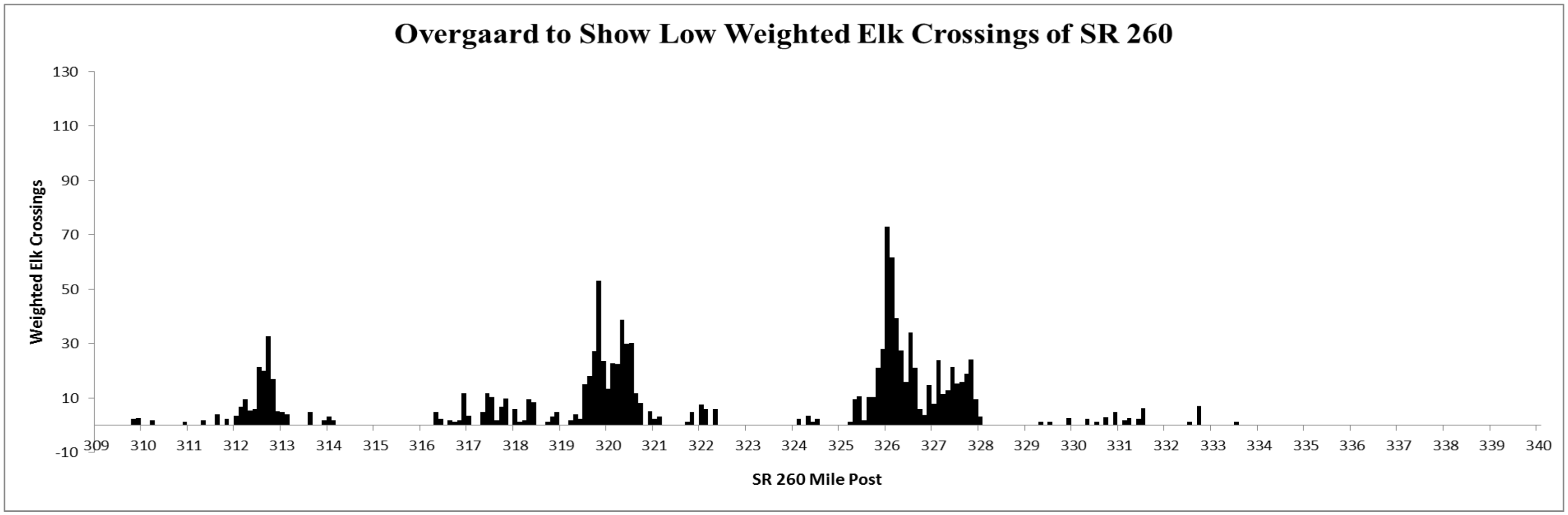


Figure 17. Weighted Elk Crossings by Milepost from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom)

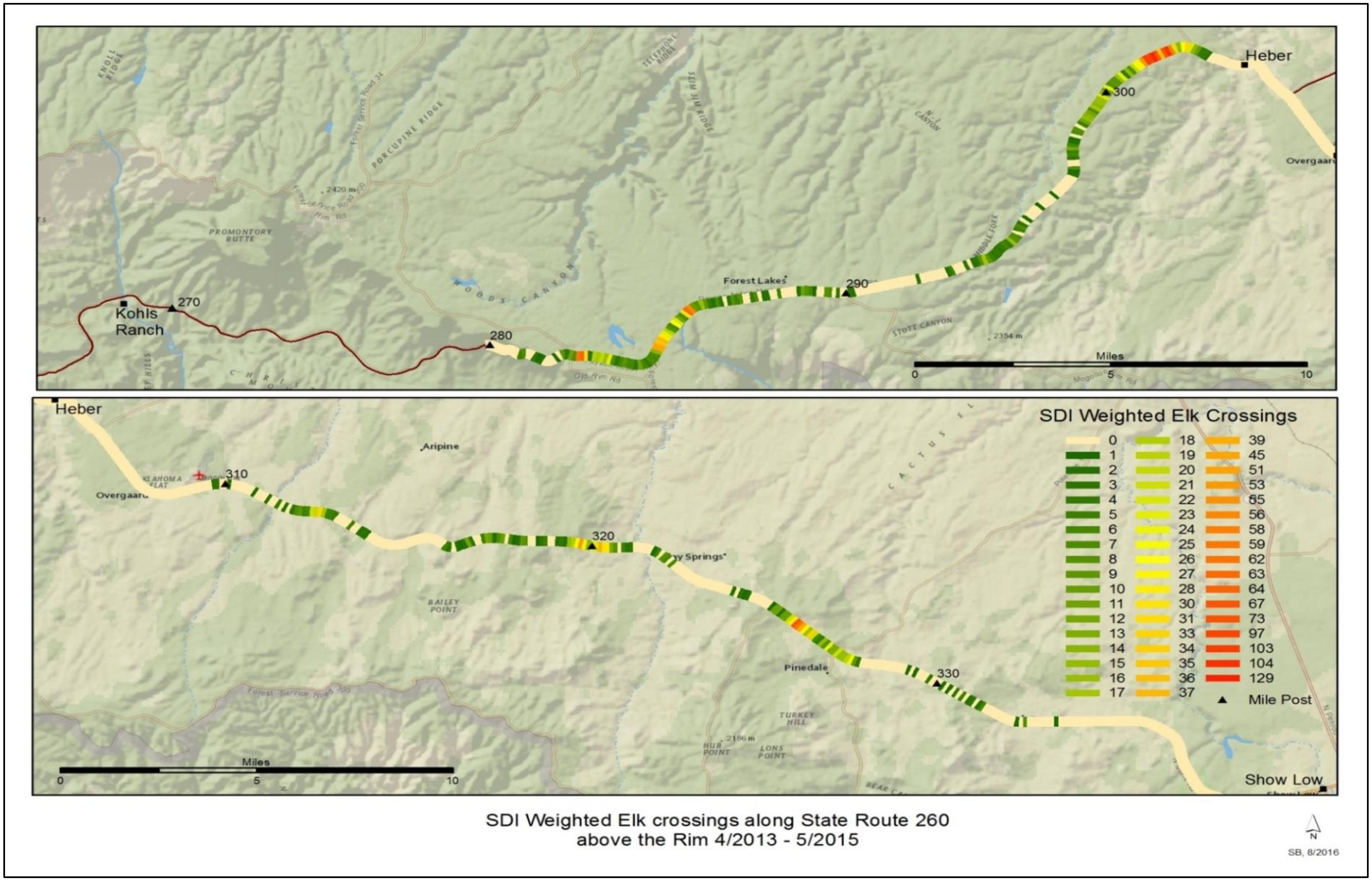
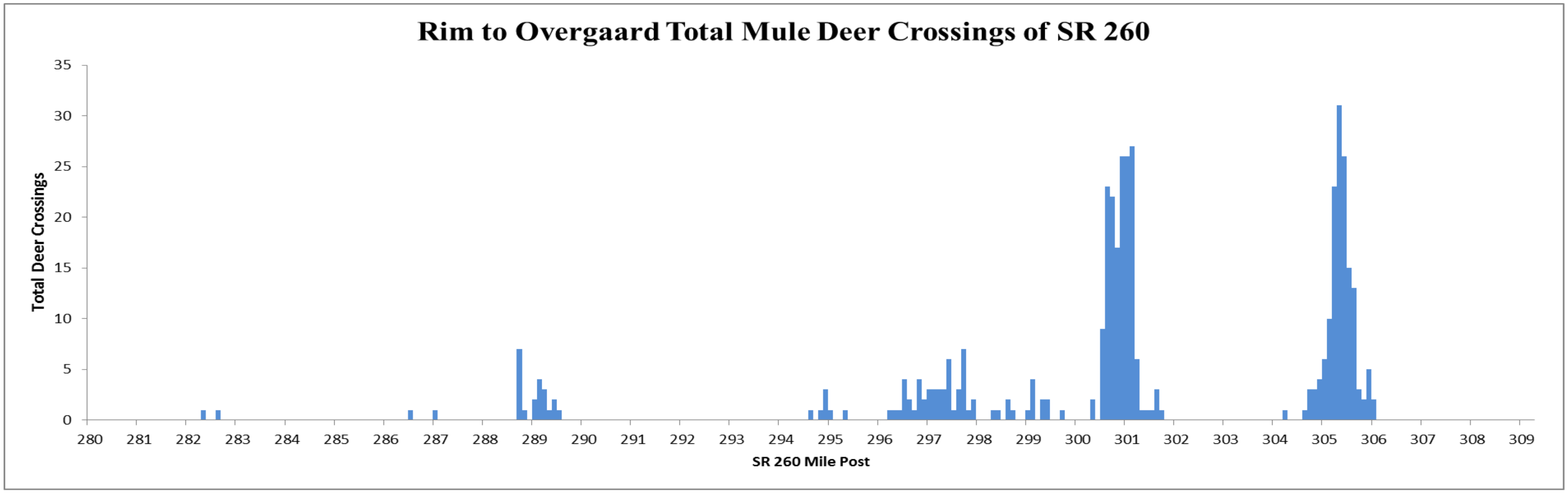


Figure 18. Weighted Elk Crossings by 0.1 mi SR 260 Segmentsfrom the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom). GPS Data Retrieved from 60 Collared Elk



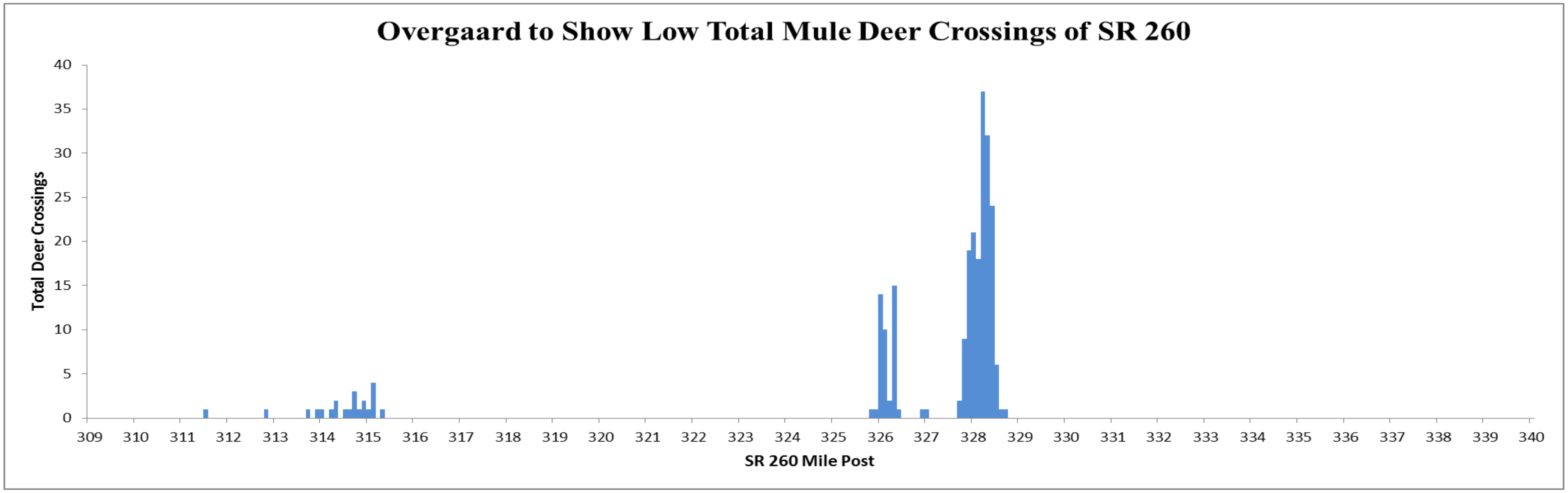


Figure 19. Total Mule Deer Crossings from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom)

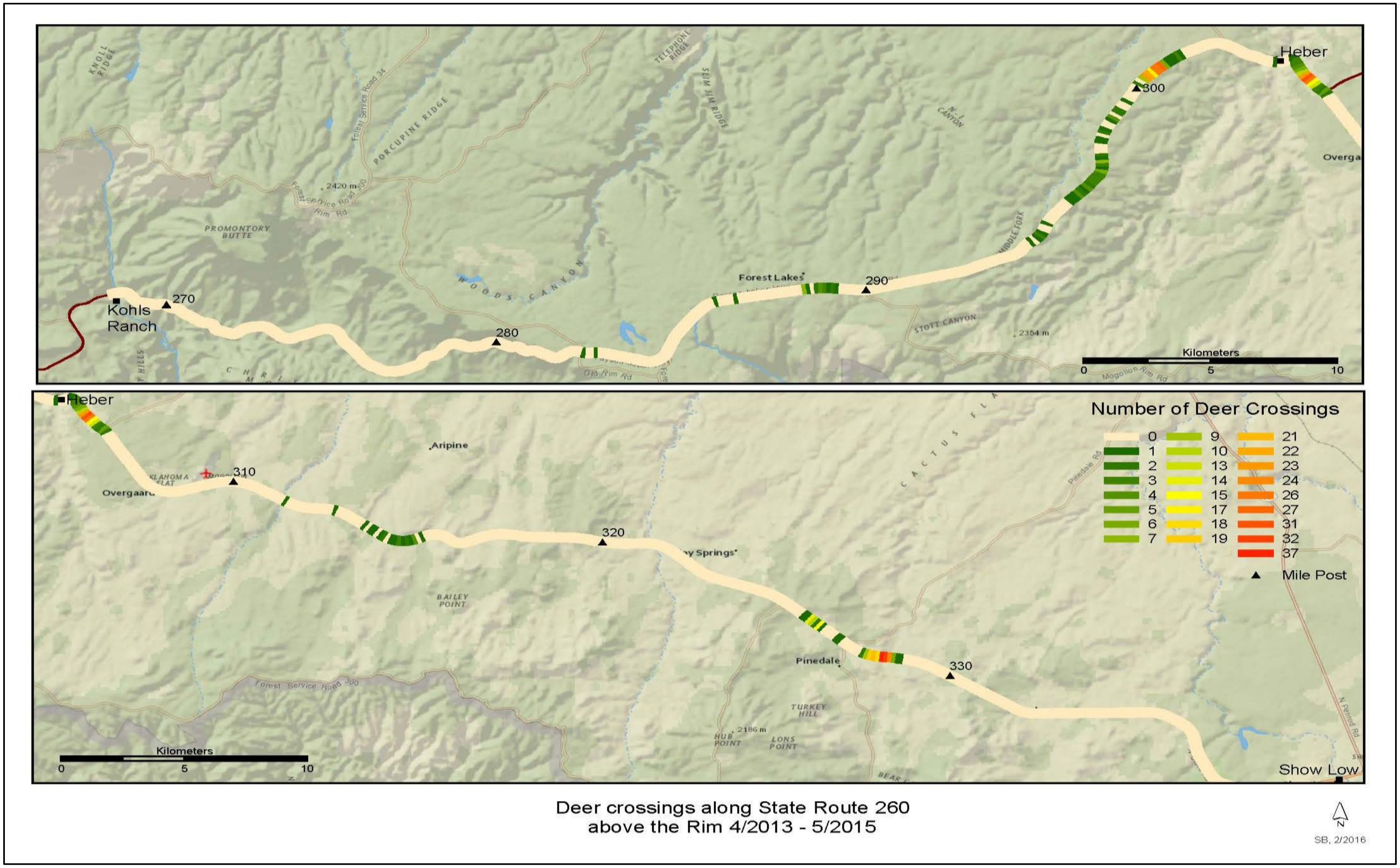
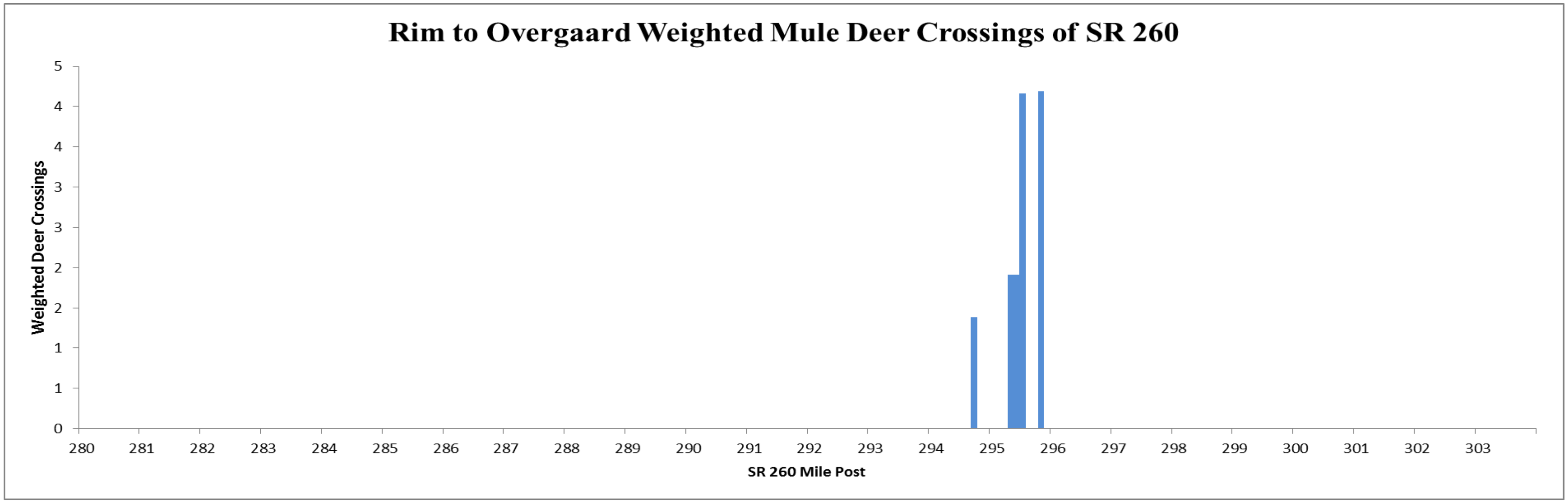


Figure 20. Weighted Mule Deer Crossings by 0.1 mi SR 260 Segments from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom). GPS Data Retrieved from 15 Collared Mule Deer



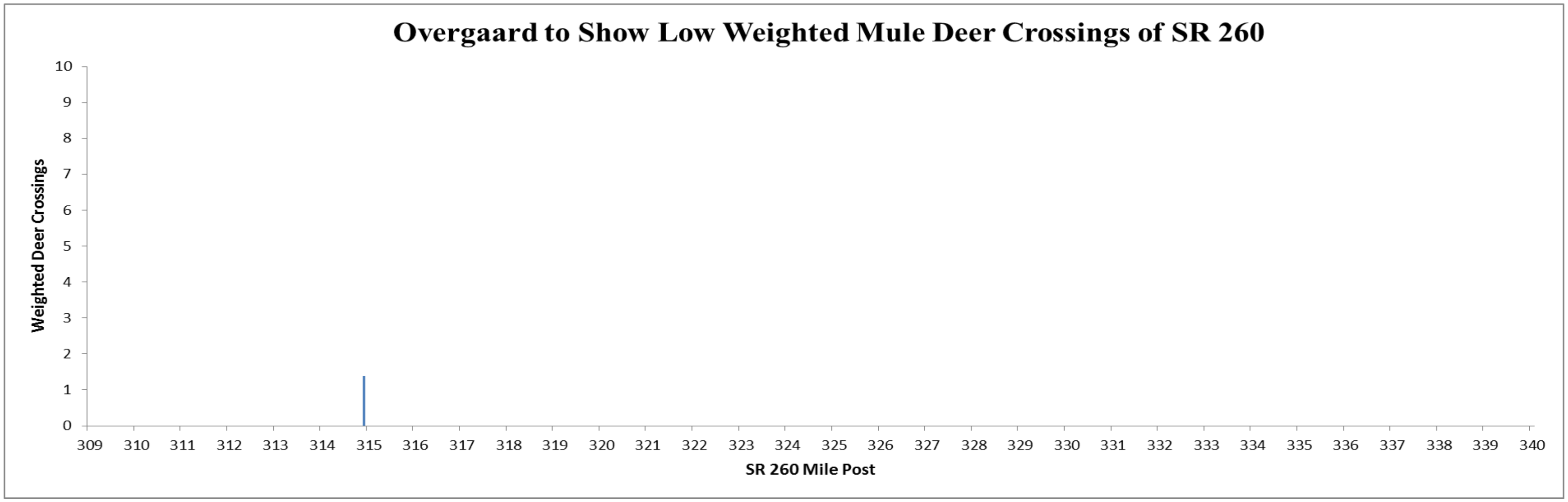


Figure 21. Weighted Mule Deer Crossings by 0.1 mi SR 260 Segments from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom). GPS Data Retrieved from 15 Collared Mule Deer

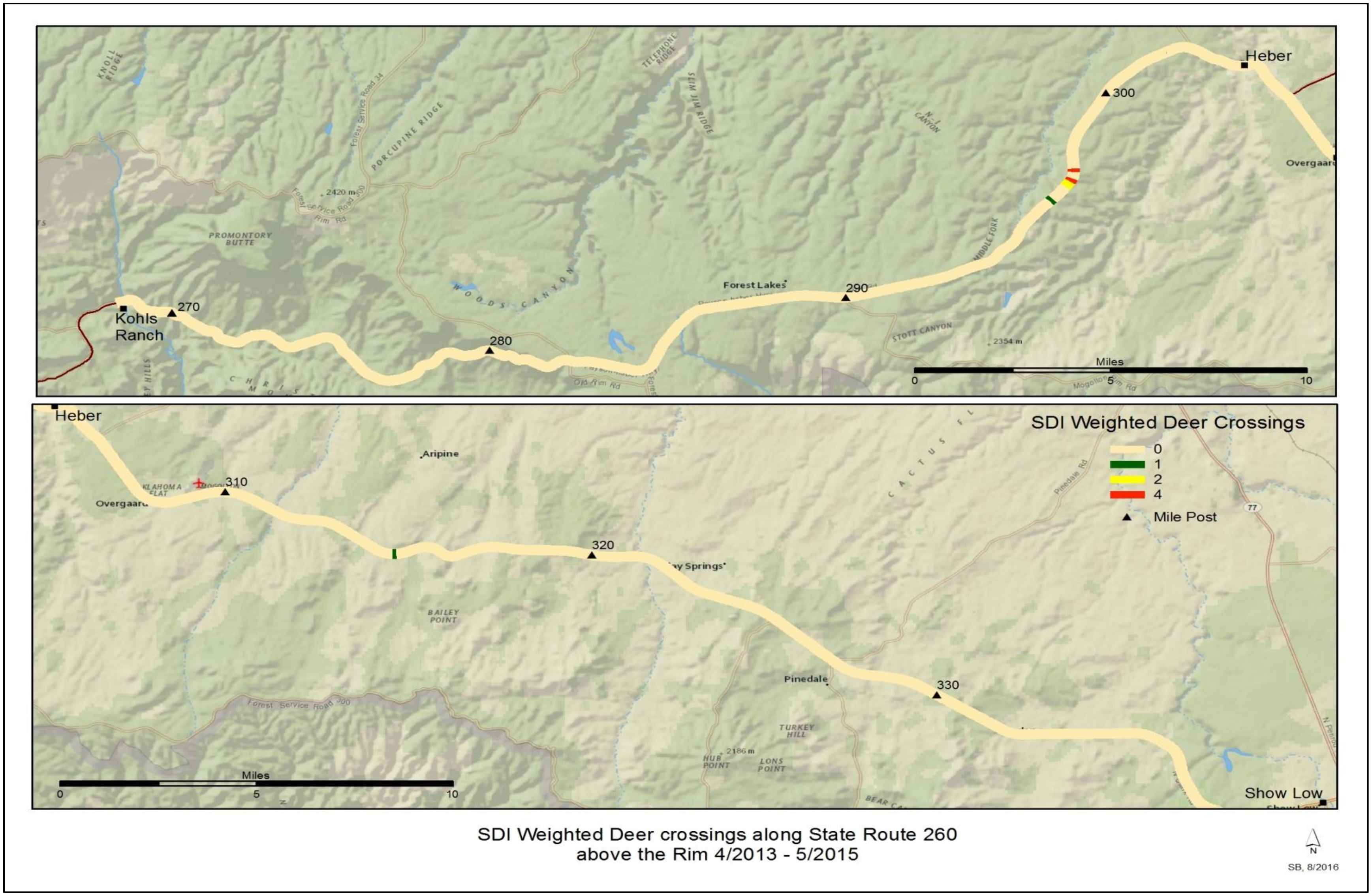


Figure 22. Weighted Mule Deer Crossings by 0.1 mi SR 260 Segments from the Mogollon Rim to Overgaard (Top) and Overgaard to Show Low (Bottom). GPS Data Retrieved from 15 Collared Mule Deer

Elk and Deer Passage Rates

Elk passage rates along SR 260 from MP 280 – 340 were 0.52 crossings/approach (±0.03). Although elk passage rates from Overgaard to Show Low (0.56 [±0.05] crossings/approach) were approximately 14 percent higher than from the Rim to Overgaard (0.50 ±0.05 crossings/approach), this difference was not significant (U = 1.39, P = 0.23). Passage rates for female elk (0.55 [±0.03] crossings/approach) were significantly higher than those for male elk (0.37 [±0.07] crossings/approach, U = 4.54, P = 0.03).

Temporally, elk passage rates by month varied slightly with the highest and lowest passage rates in April (0.54 [±0.04] crossings/approach) and March (0.43 [±0.05] crossings/approach), respectively. These differences were not significant (H = 3.96, df = 11, P = 0.97). Elk passage rates did not vary significantly by day of week and ranged from 0.49 (±0.04) crossings/approach on Sundays to 0.57 (±0.04) crossings/approach on Tuesdays (H = 3.76, df = 6, P = 0.71). Elk passage rate by time of day was significantly different and increased linearly from 0.12 (±0.02) crossing/approach between 17:00-19:00 MST to 0.92 (±0.03) crossings/approach between 05:00-07:00 MST (H = 194.65, df = 6, P < 0.001). This is likely due to a combination of reduced traffic volumes during the night and elk seeking cover before daylight (Figure 23).

Deer passage rates along SR 260 from MP 280 – 340 were 0.41 crossings/approach (±0.09). Although deer passage rates from Overgaard to Show Low (0.60 [±0.08] crossings/approach) were approximately 18 percent higher than Rim to Overgaard (0.51 [±0.08] crossings/approach), this difference was not significant (U = 0.81, P = 0.37). Passage rates for female deer (0.36 [±0.01] crossings/approach) were lower but not significantly different than those for male deer (0.61 [±0.21] crossings/approach, U = 4.54, P = 0.03). This lack of significant difference is likely due to the low number of deer used for this analysis.

Temporally, deer passage rates by month varied considerably with the highest and lowest passage rates in October (0.45 [±0.11] crossings/approach) and February (0.09 [±0.14] crossings/approach), respectively. However, these differences were not significant (H = 9.22, df = 11, P = 0.60). This lack of significance is likely due to small sample sizes. Deer passage rates did not vary significantly by day of week and ranged from 0.31 (±0.14) crossings/approach on Sundays to 0.42 (±0.10) crossings/approach on Saturdays (H = 1.69, df = 6, P = 0.95). Similar to elk, deer passage rates by time of day was significantly different and increased linearly from 0.05 (±0.08) crossing/approach between 17:00-19:00 MST to 0.59 (±0.11) crossings/approach between 03:00-05:00 MST before tapering off again at daybreak (05:00-07:00 MST, 0.44 [±0.11] crossings/approach, H = 15.37, df = 6, P < 0.02). This is also likely due to a combination of reducing traffic volumes through the night and deer behavior to seeking cover before daylight (Figure 24). Overall, deer passage rates were consistently lower than elk passage rates possibly indicating that deer have a lower tolerance for SR 260 and its' associated traffic volumes (Figure 23).

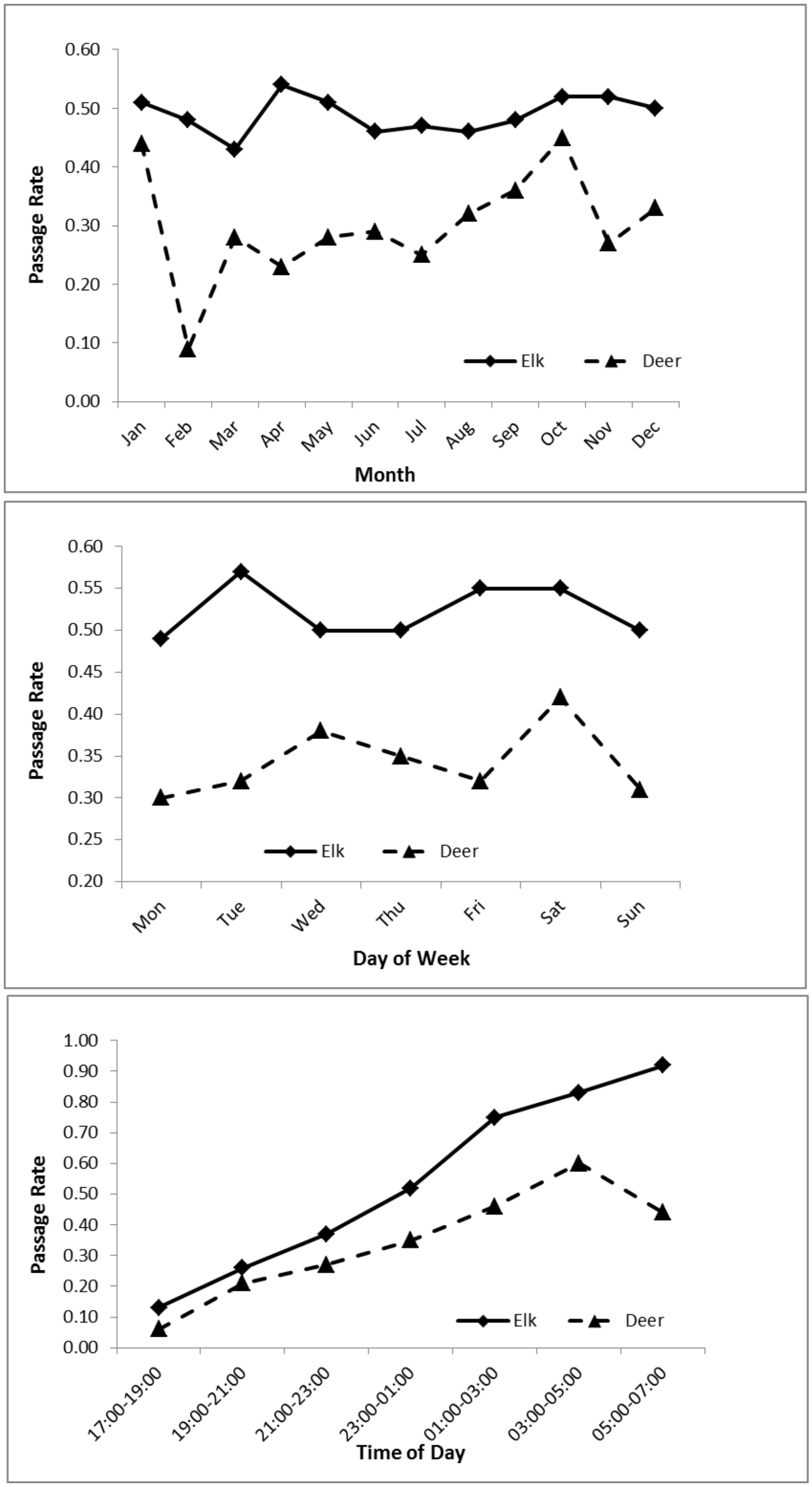


Figure 23. Comparison of GPS Determined Elk and Deer Passage Rates Along SR 260 (MP 280 – 340) by Month (Top), Day of Week (Middle), and Time of Day (Bottom)

Traffic Volume and Deer and Elk Permeability and Distribution

Elk and deer passage rates decreased significantly when traffic volumes increased (*H* = 13.56, df = 5, *P* = 0.02). At the lowest traffic volumes (<50 vehicles/hr), elk and deer passage rates were 0.69 (±0.04) and 0.46 (±0.10) crossings/approach, respectively. As traffic volume increased, passage rates for both elk and deer decreased and followed an almost identical logarithmic pattern (both species $R^2 = 0.99$) with elk consistently 0.22 (±0.01) crossings/approach higher than deer (Figure 24). Similarly, as traffic volumes decreased later in the day, elk and deer responded with increased passage rates (Figure 24).

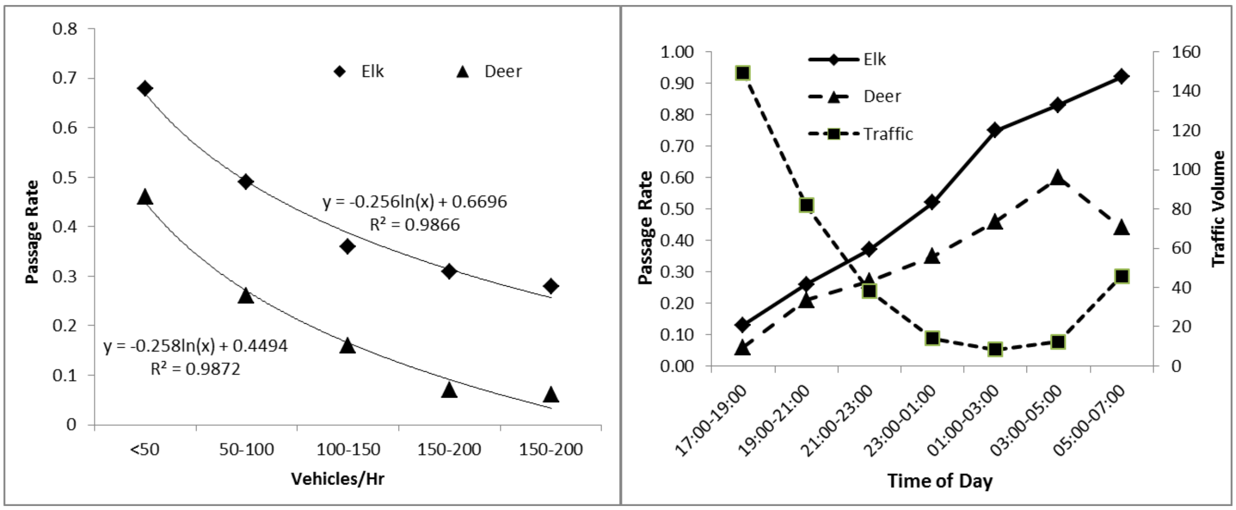


Figure 24. Elk and Deer Passage Rates Associated with Traffic Volumes Along SR 260. The Equation and R2 Value (Left Graph) Indicate Logarithmic Regression Model and Fit

The research team's elk and mule deer distribution analysis included 42,364 (elk) and 20,250 (deer) GPS locations recorded within 600 m (1980 ft) of the roadway. The mean probabilities frequency distributions showed elk and deer moving away from SR 260 as traffic volumes increased (Figure 25 and 26). The most dramatic response for each species occurred within 100 m (0.06 mi) of the roadway, where the mean probabilities of elk being within 100 m of the roadway increased from 0.02 to 0.15 as traffic volumes decreased. The deer response was higher with the mean probabilities within the same distance increasing from 0.03 to 0.24 as traffic volumes decreased. Or, another interpretation would be that the mean probabilities that elk and deer can be found adjacent to the roadway (<100 m or <1000 m) are 650 percent (elk) and 700 percent (deer) higher when traffic volumes are below 100 vehicles/hr than when they are >300 vehicle/hr.

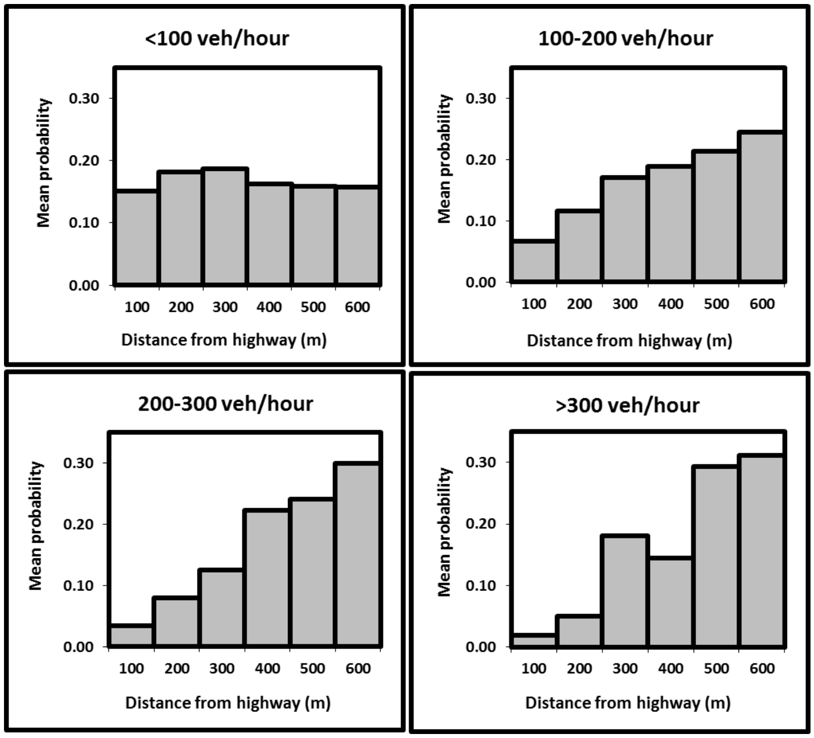


Figure 25. Mean Elk GPS Relocations Distribution by Distance from SR 260 and Traffic Volume

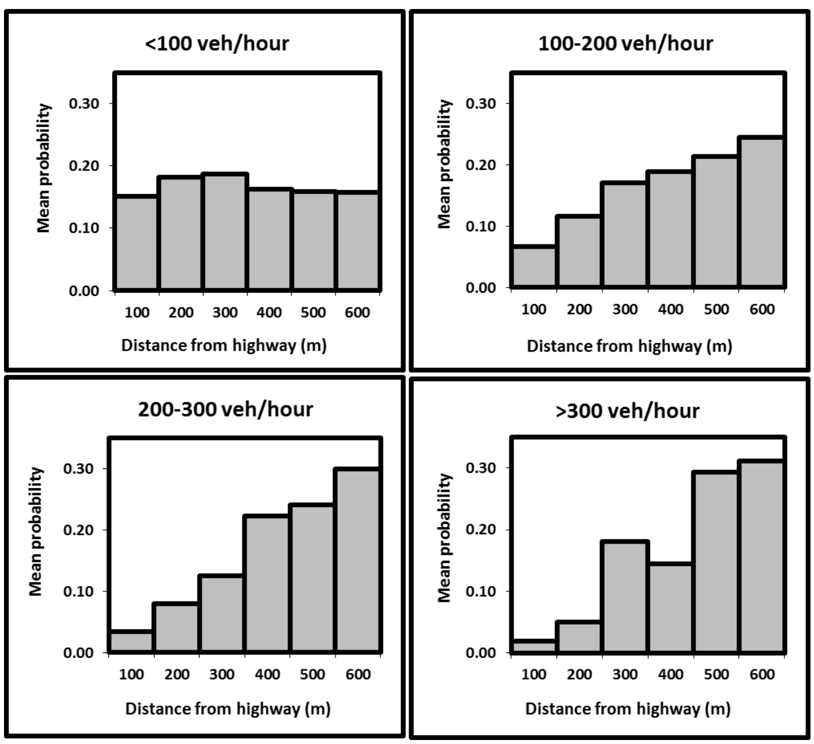


Figure 26. Mean Mule Deer GPS Relocations Distribution by Distance from SR 260 and Traffic Volume

WILD GAME COLLISIONS

The research team evaluated 2509 vehicular collisions that occurred from 2005-2015 on SR 260 between MP 280 – 340 (Figure 27). Of those collisions, 798 (32 percent) were coded "Animal_Wild_Game" in DPS crash reports. This WVC ratio is 596 percent higher than the national average of 4.6 percent . Additionally, from 2005-2015, the number and percentage of WVCs increased by 81 percent. The team documented 384 WVCs between the Rim and Overgaard and 414 between Overgaard and Show Low. The team also documented high collision areas primarily associated with undeveloped areas. Each 1.0 mi segment averaged 13.1 (±1.0) WVCs with a range of 1 to 34 (Figure 28).

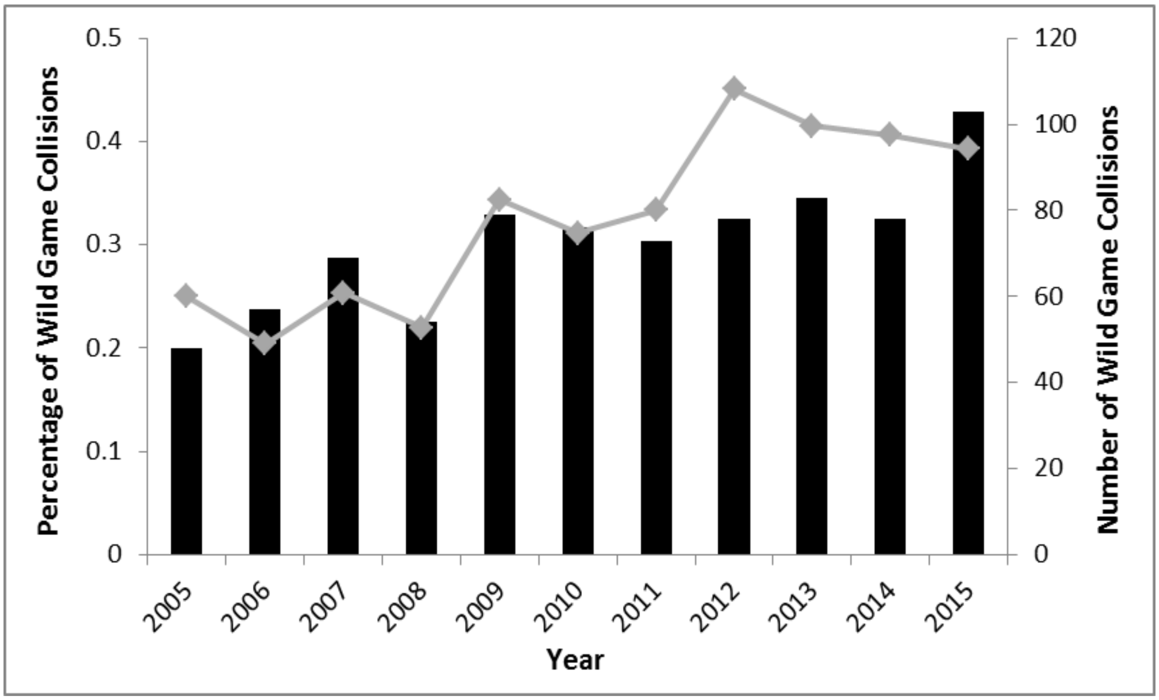


Figure 27. Yearly "Animal_Wild_Game" Crash Totals (Black Bars) and Percentage of All Crashes that are with "Animal_Wild_Game" (Grey Line) as Reported by ADOT 2005-2015 Crash Data

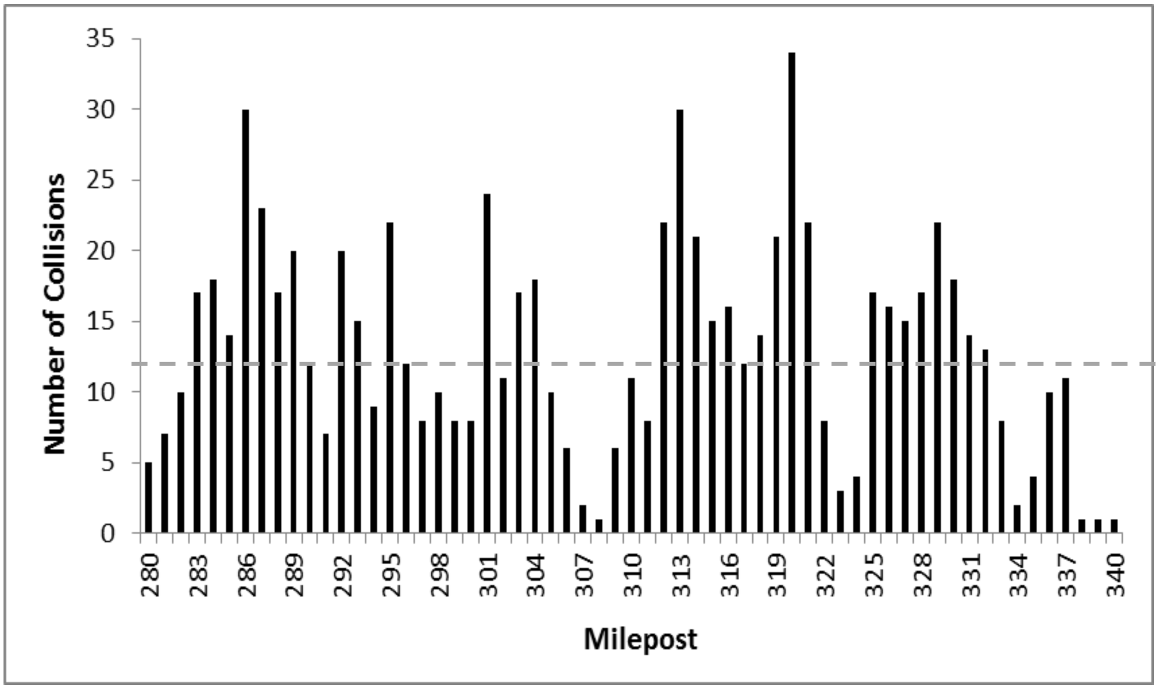


Figure 28. Total “Animal_Wild_Game” Collisions (Black Bars) and Mean “Animal_Wild_Game” Collisions (Grey Line) by Milepost as Reported by ADOT 2005-2015 Crash Data

The yearly rates of WVCs along SR 260 followed the basic trend of traffic volumes: as traffic volumes decreased or increased, so did WVCs (Figure 29).

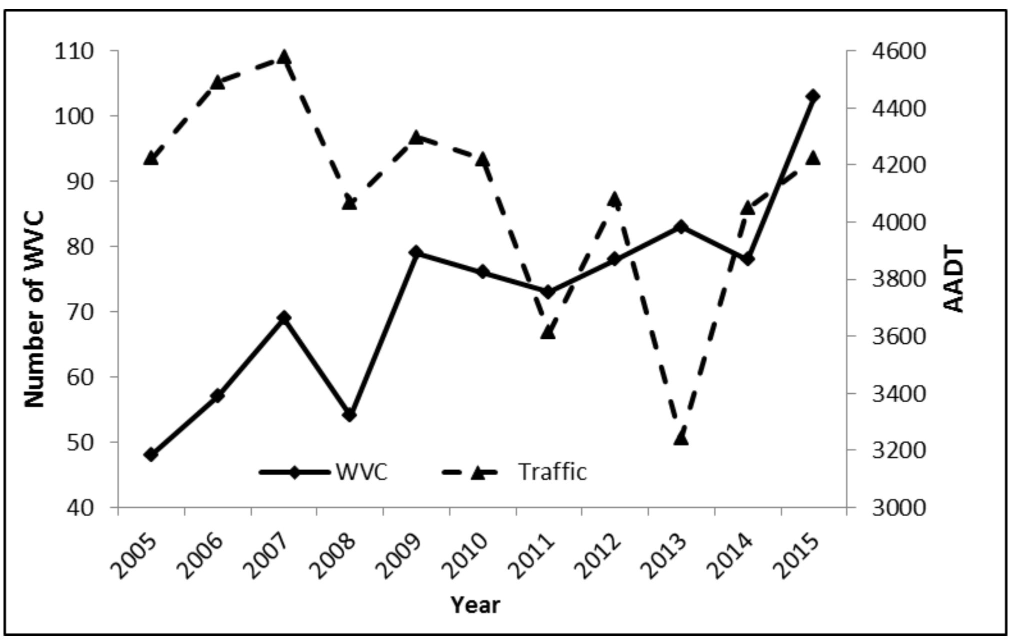


Figure 29. Yearly Rates of Wildlife-Vehicle Collisions (WVC) Compared to Average Annual Daily Traffic (AADT) Volumes Along SR 260 from the Mogollon Rim to Show Low (2005-2015)

Figures 30a-c compare WVC totals to AADT by when they occurred. Monthly WVCs averaged 66.5 (±8.8) with the highest number occurring in October (128)—the month that elk mate (Figure 30a). June and July showed the second highest number of collisions (95). This number of monthly WVCs is 43 percent above the monthly average for the area and correlates with a 39 percent increase above mean traffic volumes in June and July. February showed the lowest number of collisions (26).

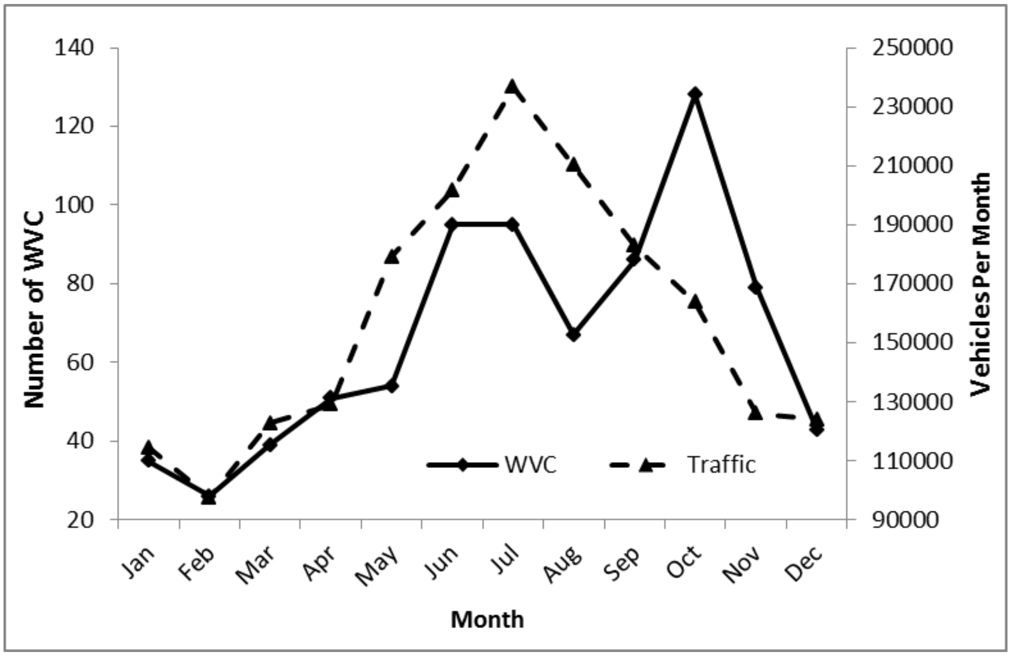


Figure 30a. Monthly Occurrence of Wildlife-Vehicle Collisions (WVC) Compared to Traffic Volumes Along SR 260 from the Mogollon Rim to Show Low (2005-2015)

Day of the week collisions averaged 114.0 (±4.9) with Fridays having an average of 22 percent more WVCs than any other day of the week (Figure 30b). Correspondingly, Fridays also had an average of 25 percent more traffic volume.

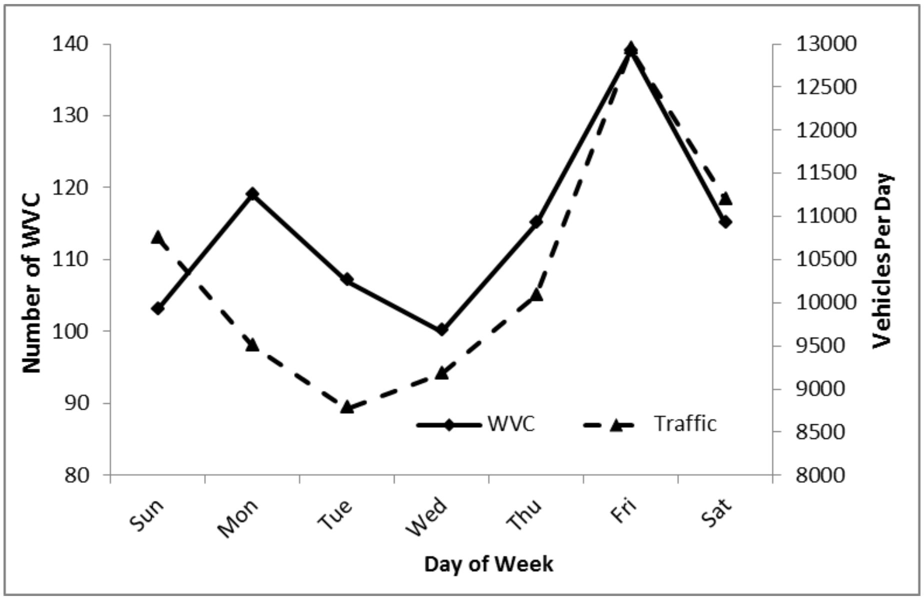


Figure 30b. Daily Occurrence of Wildlife-Vehicle Collisions (WVC) Compared to Traffic Volumes Along SR 260 from the Mogollon Rim to Show Low (2005-2015)

Time of day data showed the most WVCs at 20:00 MST—the time when elk become active and traffic volumes are relatively high (Figure 30c). The second highest peak in collisions occurred around 05:00 MST as traffic volumes are beginning to increase. Elk and deer are primarily active near roadways at night, or nocturnal, however they generally begin their nocturnal activity at dusk return to beds or areas further from roads just after dawn. The increased traffic volumes during the day and the nocturnal behavior of elk and deer likely contribute to the peaks at 20:00 and 05:00 (Figure 30c).

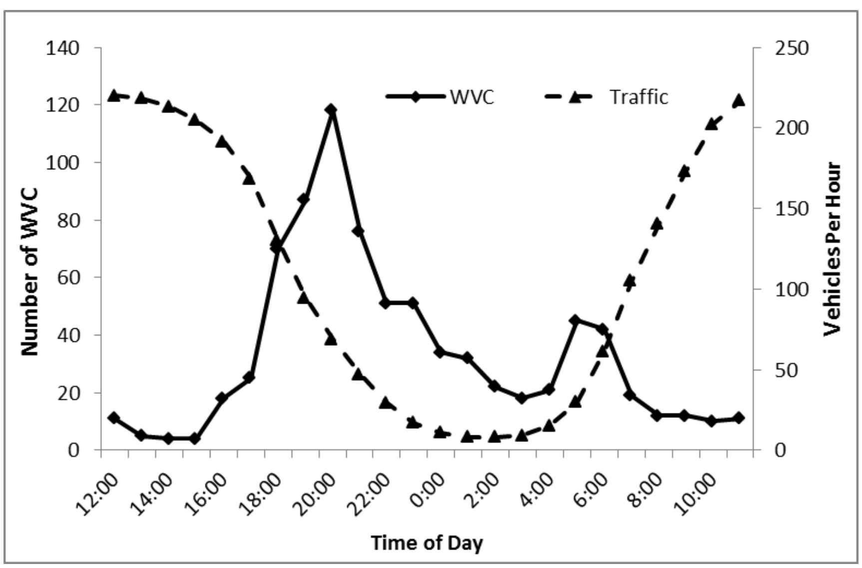


Figure 30c. Hourly Occurrence of Wildlife-Vehicle Collisions (WVC) Compared to Traffic Volumes Along SR 260 from the Mogollon Rim to Show Low (2005-2015)

Elk and deer population survey results were available for 2006-2015 and estimated that elk and deer populations averaged 2997.7 (±325.3) and 1452.5 (±315.1), respectively. Elk populations fluctuated from 1978 (2010) to 4690 (2013) but generally remained constant. Mule Deer populations increased dramatically from 439 (2007) to 3784 (2015); see Figure 31. Since the elk population and traffic volumes generally did not increase from 2006-2015, the local deer populations increase of 402 percent potentially contributed to the 81 percent WVCs increase during this period.

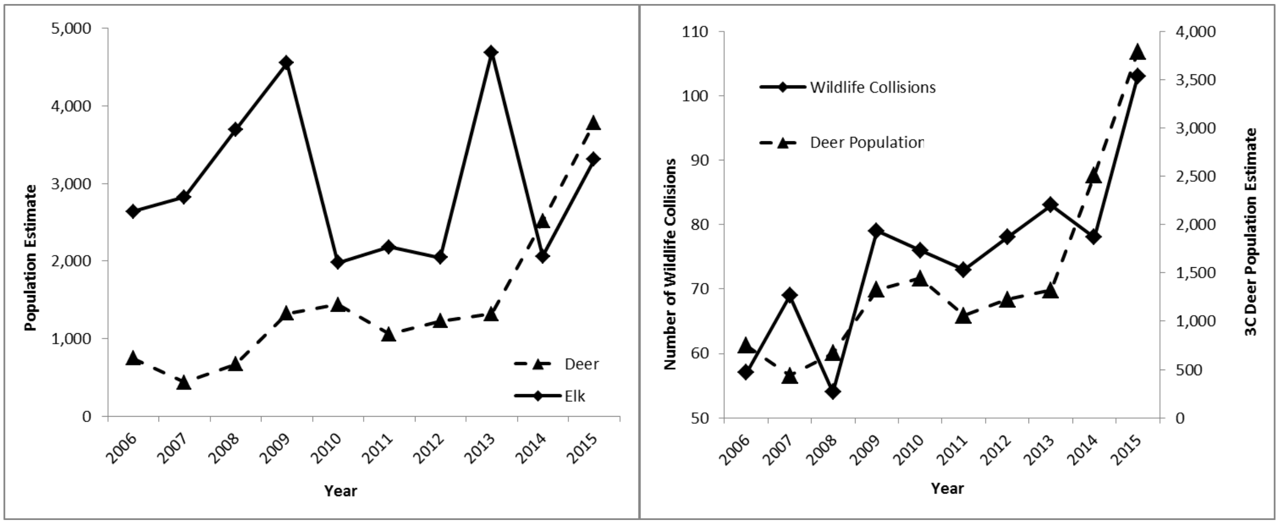


Figure 31. Yearly Local Elk and Deer Population Estimates (Left) and Comparison of Deer Populations to Total Number of Wild Game Collisions Reported in ADOT on SR 260 from MP 280-309 (2006-2015)

RATINGS FOR PLACEMENT OF WILDLIFE CROSSING LOCATIONS

The 60 – 1 mi segment ratings ranged from 3 to 37 (mean 19.7 [± 1.3]) with the lowest rated segments corresponding with human populated areas (Forest Lakes, Heber, Overgaard, Clay Springs, Pinedale, and Show Low) and the highest rated segments corresponding to sparse or absent human population. WCS locations were primarily determined by using the upper 99 percent CI, which included ratings ≥ 23 (N = 23; Figure 32). Overall, ratings were relatively similar for areas west and east of Overgaard, however, as SR 260 approaches Show Low and human development increases, ratings dropped off considerably.

These ratings were the culmination of a detailed, combined analysis that included WVCs, GPS determined elk and deer crossings, land ownership, human development levels, topography, presence or absence of existing structures, and in the case of Overgaard to Show Low, the input from the Wildlife TAC: See *Chapter 5 – Wildlife Crossing Location Recommendations for State Route 260 Mogollon Rim to Show Low* for detailed location information.

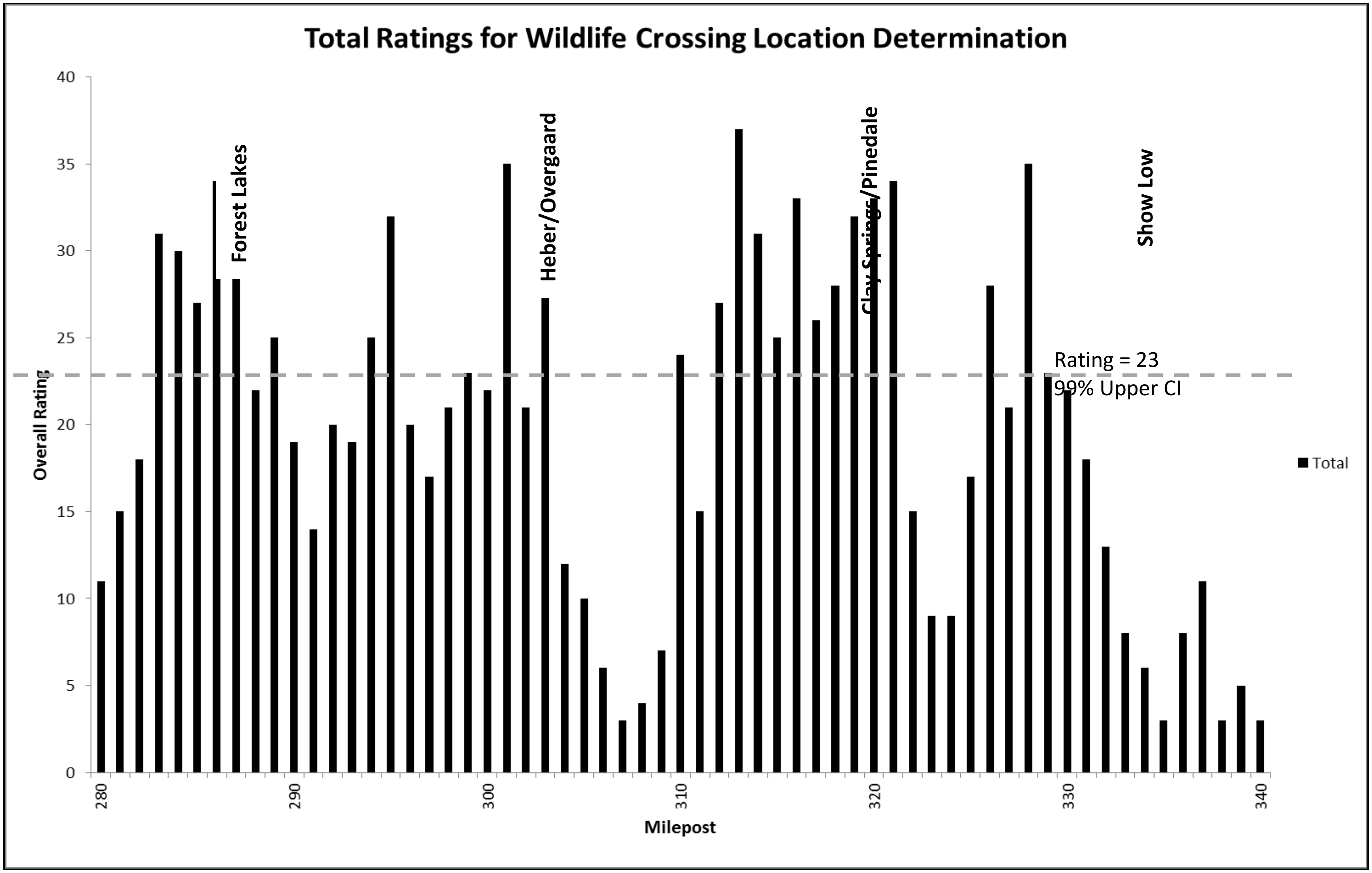


Figure 32. Total Wildlife Crossing Location Ratings (Black Bars) by Milepost and Upper 99% Confidence Interval (Dashed Line) for SR 260 from the Mogollon Rim to Show Low

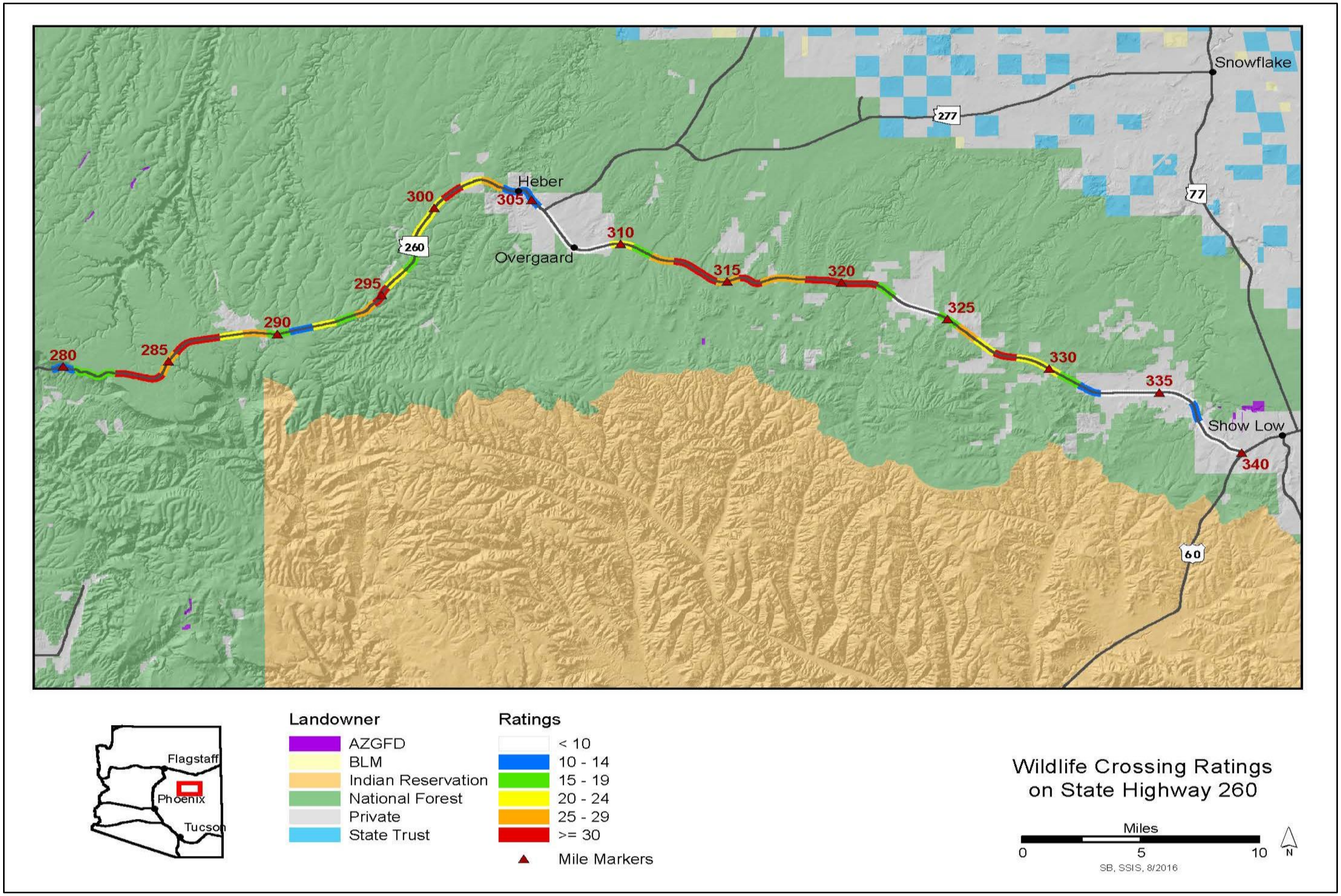


Figure 33. Color Coded Ratings for Wildlife Crossing Locations Along SR 260 from Mogollon Rim to Show Low

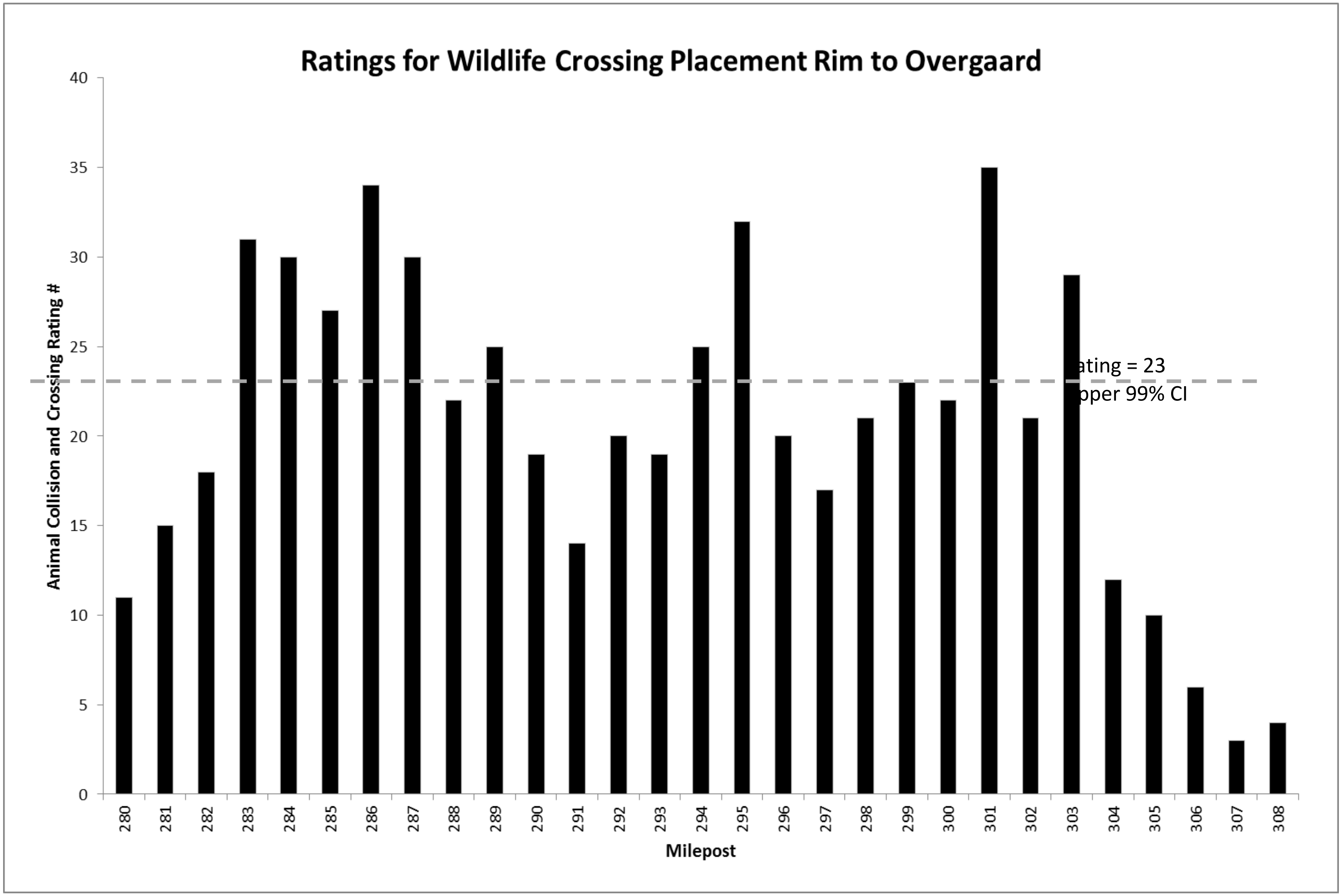


Figure 34. Overall Ratings from the Mogollon Rim to Overgaard (MP 280-308) and Upper 99% Confidence Interval for Ratings (Dashed Line)

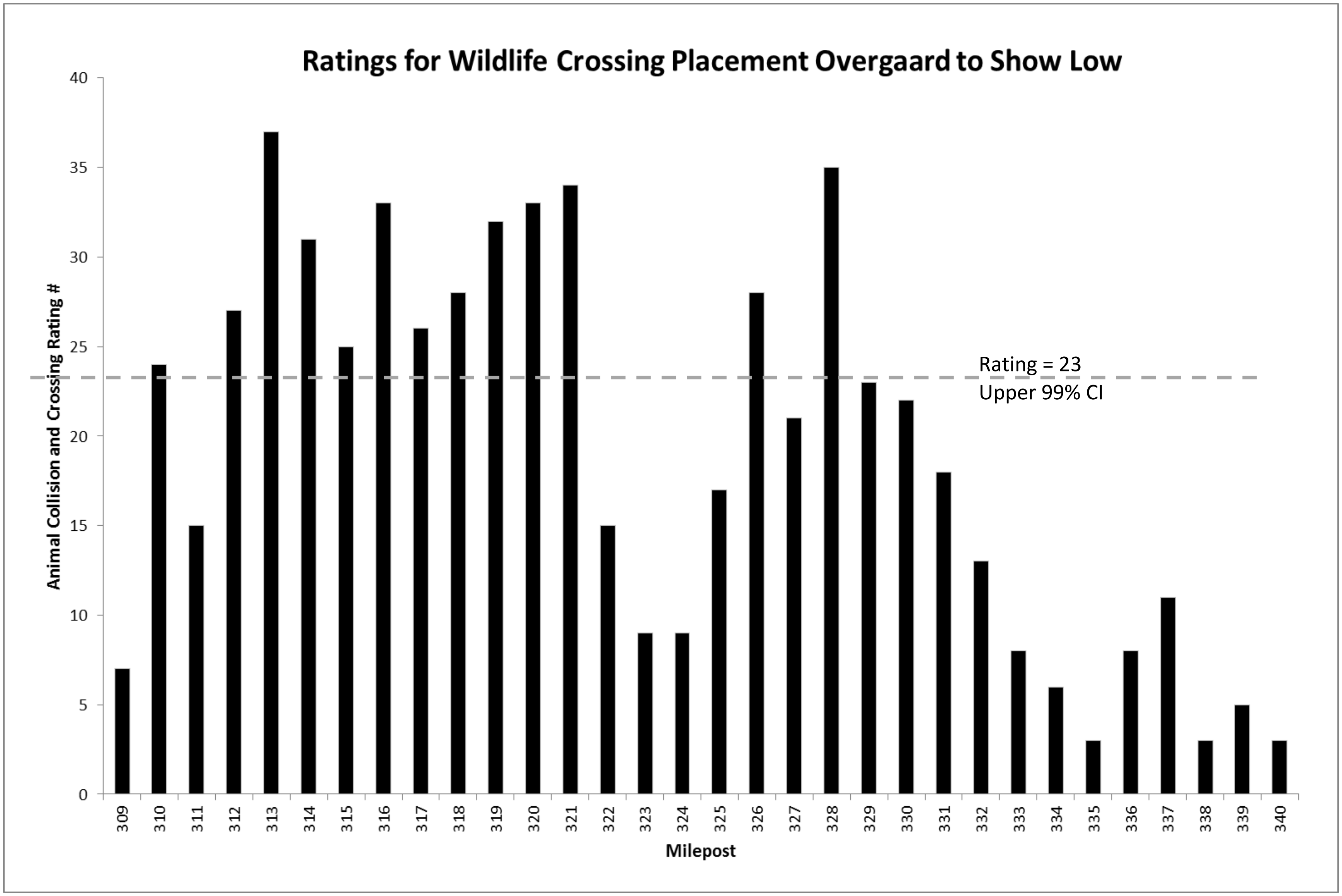


Figure 35. Overall Ratings for Overgaard to Show Low (MP 309-340) and Upper 99% Confidence Interval for Ratings (Dashed Line)

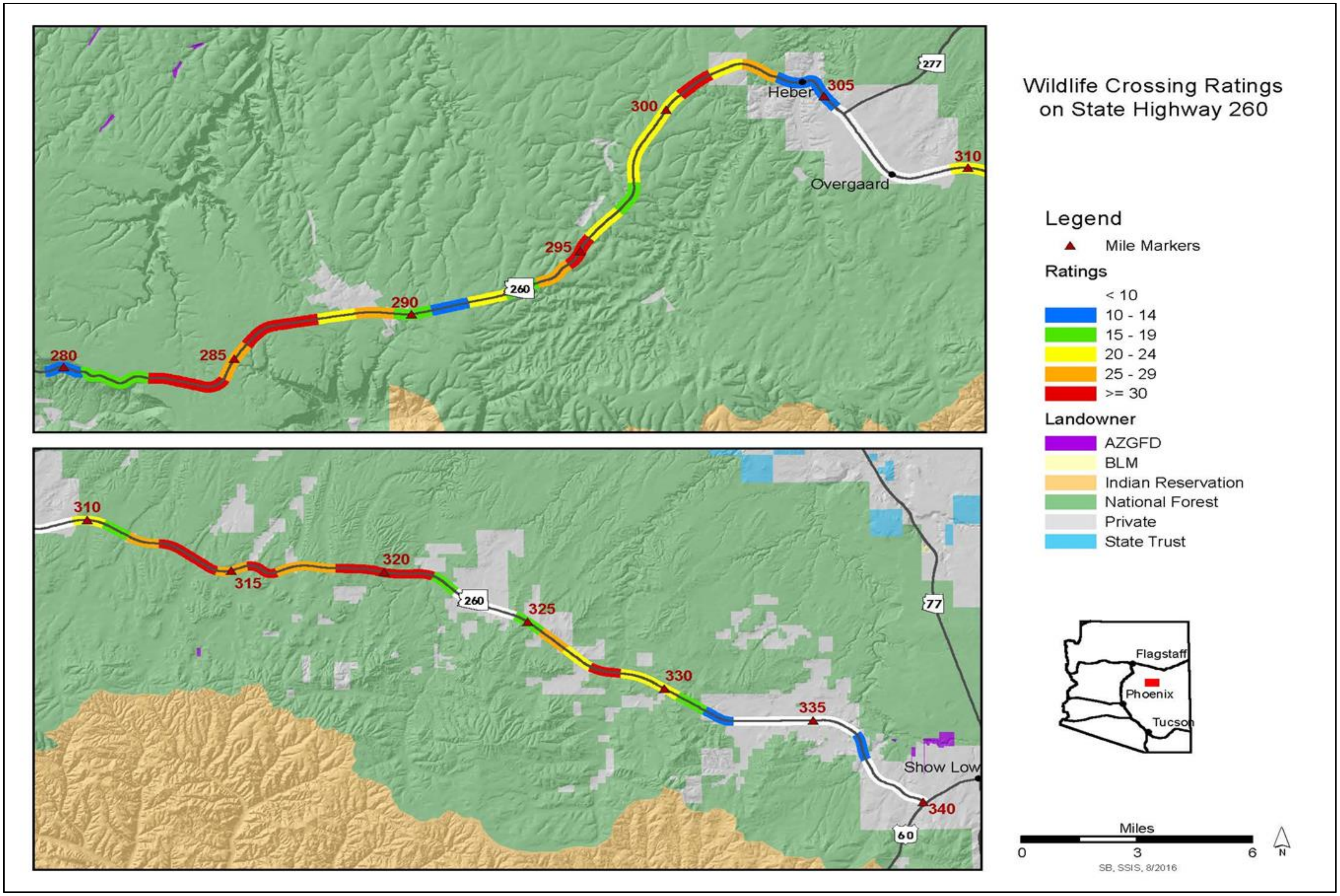


Figure 36. Color Coded Ratings for Wildlife Crossing Locations Along SR 260 from the Mogollon Rim to Show Low

CHAPTER 5: OPTIONS FOR CROSSING LOCATIONS AND FENCING

OVERVIEW

The research team identified and prioritized SR 260 WCS locations between the Rim (MP 280) and Show Low (MP 340). The structures, along with exclusion ROW fencing, would serve the objectives by funneling animals away from the roadway for underpass crossings while maintaining habitat connectivity for elk, deer, and other wildlife. To identify and prioritize structure location, the team used a rating system that divided SR 260 into 60 segments, each 1 mi long, and incorporated collision reduction, habitat connectivity, and pertinent variables: elk and deer GPS roadway crossing data, WVC locations, terrain suitability, human activity levels, and land status or ownership (See Chapter 4 for Results). Once the roadway segments were rated, the research team prioritized the highest-rated 1.0 mi segments (greater than 23 based on a 99 percent upper CI) and considered them in relation to two factors: existing, suitable bridges for wildlife underpass crossings and the distance between WCS. In order to balance habitat connectivity and reconstruction fiscal constraints, the team increased the suggested distance between structures to approximately three miles. This rating approach resulted in 18 potential crossing locations: eight west of Overgaard (MP 280 – 309) and 10 east of Overgaard (MP 309 – 340). Previous Arizona studies indicate that structures placed two to three miles apart will limit elk ability to successfully cross over the roadway via a wildlife OP or cross under at a roadway bridge (Figure 37). The increased WCS spacing, although not ideal, would not be cost prohibitive and would still encourage larger wildlife to safely cross beneath roadway structures at controlled intervals. The expanded spacing is not viable for smaller wildlife species.

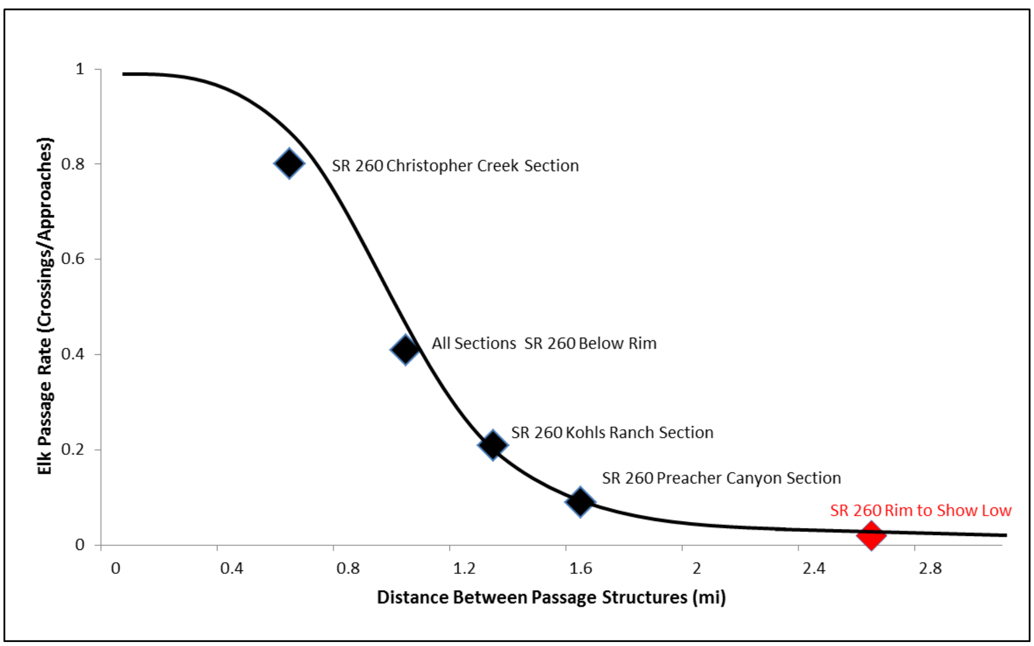


Figure 37. Elk Passage Rates in Relationship to Wildlife Crossing Structure Spacing: Comparing Previous Studies (Black Diamonds) to Predicted (Black Line) Overall Passage Rate

for SR 260 Mogollon Rim to Show Low (Red Diamond)

Assuming Passage Structure Spacing and Fencing Follow Recommendations in this Study

Below, the research team provides potential WCS placements based on ratings and the two post-rating factor adjustments. The locations are separated into two roadway segments: the Rim (MP 280) to Overgaard (MP 309) and Overgaard (MP 309) to U.S. 60 at Show Low (MP 340.1).

POTENTIAL LOCATIONS FOR WILDLIFE CROSSINGS – OVERGAARD TO SHOW LOW

The final WCS locations will be determined by the Wildlife Connectivity TAC during the Final Design phase. To inform the TAC's decision making process, the research team has provided concise recommendations that include the phase 1 preliminary locations that had been previously identified and reviewed by the TAC's multidisciplinary team of biologists, engineers, and project managers.

This research team's evaluation criteria included the Wildlife Connectivity TAC's Phase 1 preliminary crossing locations, along with updated WVC location data, GPS determined elk and deer crossing locations, land ownership, human development levels, topography, presence or absence of existing structures, and the distance between proposed or existing structures. Based on the evaluation, the team identified the following 1 mi segments (e.g., MP 310 would be the roadway between MP 309.5 and 310.5) as the most likely effective WCS locations : MP 310, 312, 314, 316, 318, 319, 321, 326, 328, and 330 (Figure 38).

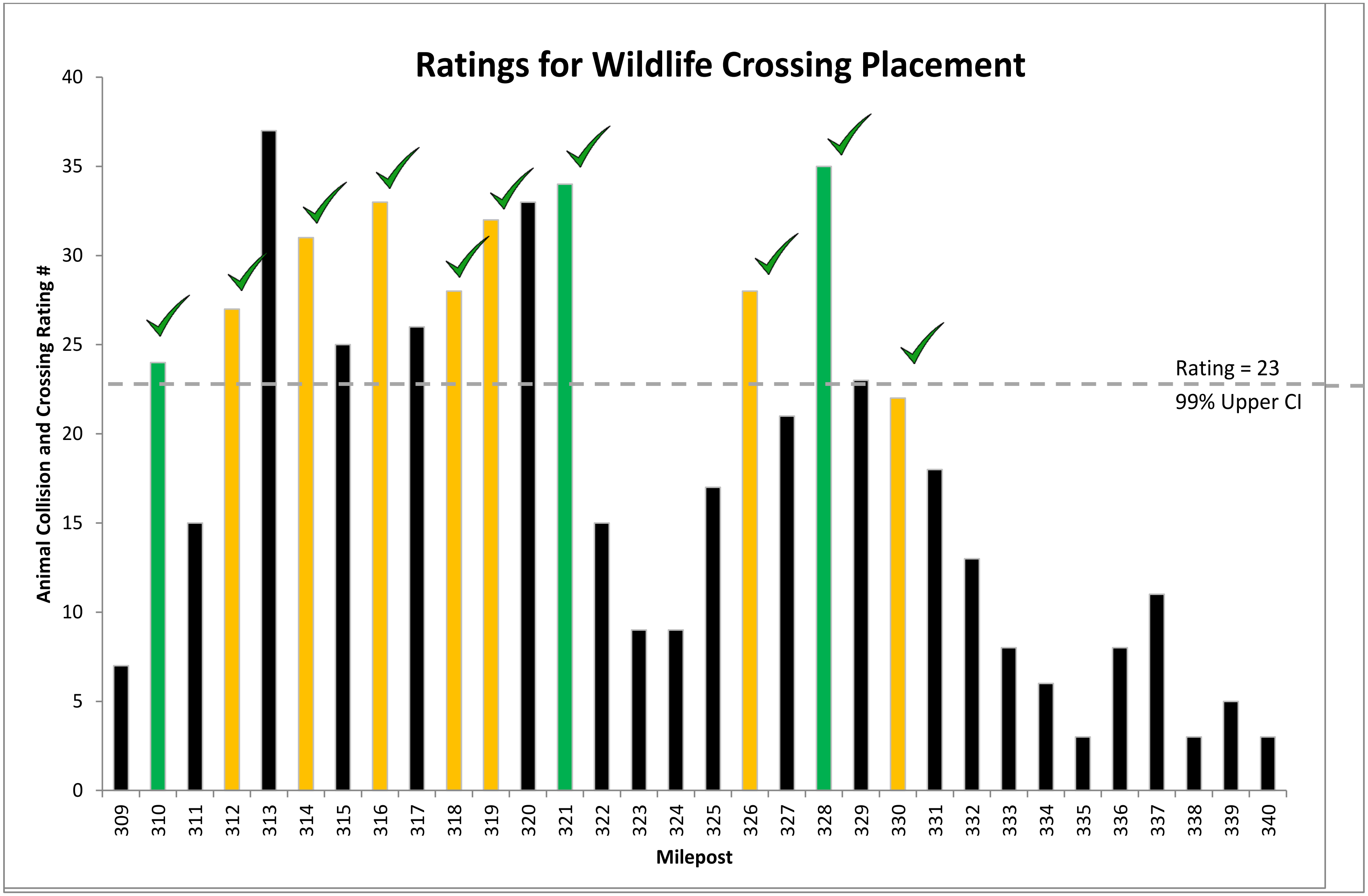


Figure 38. Potential Wildlife Crossing Placement on SR 260: Overgaard to Show Low

Overall Ratings Based on Upper 99 Percent Confidence Interval (**Dashed Line**) and Suitable WCS Spacing

Green Check Mark = Selected Wildlife Crossing Structure Locations; **Black Bar =** Areas not Selected for Future Mitigation; **Green Bar =** Existing Structure Suitable for Wildlife Passage; **Orange Bar =** Recommended Location for WCS

For each 1 mi segment, the research team selected the locations described in the *Preliminary Wildlife Crossing Matrix* (PWCM)*.* These locations and selection rational are described in the following pages.

MP 310.05 (Station 231+85) – This location, the Pierce Wash Bridge (Figure 39), exceeds a rating of 23, fulfills WCS spacing needs, and is an existing structure that could serve as a dual-purpose drainage and WCS, eliminating additional wildlife related project costs. Pierce Wash Bridge is a three-span 81 ft bridge that provides the openness (width and 15 ft vertical clearance) needed to encourage wildlife to cross beneath.

Figure 39. Pierce Wash Bridge at MP 310.05

MP 312.31 (Station 350+89) – This location exceeds a rating of 23, fulfills WCS spacing needs, and is an existing 10 ft by 10 ft reinforced concrete box culvert (RCBC) that could be replaced with bridges to address existing sedimentation issues and serve as a dual-purpose drainage and WCS. This RCBC is located in a high fill area that would permit the new bridge to have the recommended vertical clearance (15 ft) for wildlife to cross beneath while not altering the existing road profile.

MP 313.84 (Station 433+155) – This location exceeds a rating of 23, fulfills WCS spacing needs, and exists as three 12 ft by 10 ft RCBCs that could be replaced with bridges and serve as a dual-purpose drainage and WCS allowing wildlife to cross beneath. This RCBC is located in an area that would require the road profile to be raised a minimum of 5 ft. (Figure 40).

Figure 40. Decker Wash Culvert MP 313.84

MP 315.69 (Station 529+00) – This location(Figure 41) exceeds a rating of 23, fulfills WCS spacing needs, and would require a 230 ft by 100 ft wildlife OP. Although the TAC selected nearby Day Wash as an acceptable potential WCS location, the research team's evaluation determined that a structure at this location would best meet project needs. Additionally, bridge design improvements (e.g., precast arch bridges) may negate the Day Wash project budget advantage.

Figure 41. Cut Suitable for Building Wildlife Overpass near MP 315.69

MP 318.15 (Station 660+00) – This location (Figure 42) exceeds a rating of 23, fulfills WCS spacing needs, and is an existing 10 ft by 8 ft RCBC that could be replaced with bridges to serve as a dual-purpose drainage and WCS. This RCBC is located in a high fill area that would permit the new bridges to have the recommended vertical clearance (15 ft) for wildlife to cross beneath while not altering the existing road profile. The Wildlife TAC previously approved this location in the PWCM.

Figure 42. Bagnal Wash at MP 318.15

MP 319.31 (Station 723+00) – This location (Figure 43) exceeds a rating of 23, fulfills WCS spacing needs, and would require a 230 ft by 100 ft wildlife OP. Bridge design improvements (e.g., precast arch bridges) may reduce the original cost estimate for this location's OP.

Figure 43. Possible Wildlife Overpass Location at MP 319.31

MP 321.25 (Station 825+26) – This location, Cottonwood Wash Bridge (Figure 44), exceeds a rating of 23, fulfills WCS spacing needs, and is an existing structure that could serve as a dual-purpose drainage and WCS, eliminating additional wildlife related project costs. Cottonwood Wash Bridge is a three-span 175-ft bridge that provides marginal openness (9-ft vertical clearance) for wildlife to cross beneath, but should be suitable due to the structure's width and the addition of exclusion fencing to guide animals under the structure.

Figure 44. Cottonwood Wash Bridge at MP 321.25

MP 325.91 (Station 1069+50) or alternate location at MP 324.62 (Station 998+54) – This location exceeds a rating of 23, fulfills WCS spacing needs, and has two existing 96-inch corrugated metal pipes (CMPs) that could be replaced with bridges to serve as dual-purpose drainage and WCS. These CMPs are located in an area that would permit the new bridges to have the recommended vertical clearance (15 ft) for wildlife to cross beneath while not altering the road profile. Although the Wildlife Connectivity TAC did not previously recommend this location for a WCS, the research team used updated information, the ratings, and proximity to water sources and meadows to deem this location suitable to be added to the project's final design. One concern at this location is the presence of houses; ADOT would have to evaluate current and future housing development plans during final design.

If development is imminent, another alternative to meet the spacing requirements would be a strip of USFS land about 1 mi west of these culverts at MP 324.62. (Figure 45) This location has cut slopes adequate for an OP and is oriented on a strip of ASNF land that would minimize the potential for development in the future and is more suitable as a long-term solution. Because this alternate location was not included in the preliminary analysis by the TAC, it would require a TAC review during final design.

Figure 45. Alternate Overpass Location at MP 324.62

<u>MP 328.32 (Station 1196+00)</u> – This location exceeds a rating of 23, fulfills WCS spacing needs, and is an existing structure (Mortensen Wash Bridge, Figure 46) that could serve as a dual-purpose drainage and WCS; thus, eliminating additional wildlife related project costs. Mortensen Wash Bridge is a three-span 175 ft bridge that provides the openness (width and 15 ft vertical clearance) needed to encourage wildlife to cross beneath. This structure is one of the best wildlife structures on SR 260.

Figure 46. Mortensen Wash Bridge at MP 328.32

MP 329.46 (Station 1256+50) – This location at Colbath Wash (Figure 47) exceeds a rating of 23, fulfills WCS spacing needs, and has four existing 96 inch CMPs that could be replaced with bridges to serve as a dual-purpose drainage and WCS for wildlife to cross beneath. These CMPs are located in an area that has additional fill material, which would add to the new bridge's vertical clearance for wildlife. The Wildlife Connectivity TAC previously approved this location in the PWCM.

Figure 47. Colbath Wash Culvert at MP 329.46

POTENTIAL LOCATIONS FOR WILDLIFE CROSSINGS – MOGOLLON RIM TO OVERGAARD

The research team's evaluation criteria included updated WVC location data, GPS-determined elk and deer crossing locations, land ownership, human development levels, topography, and the distance between potential or existing structures. Based on the evaluation, the team identified eight one-mile segments (e.g., MP 283 would be the roadway between MP 282.5 and 283.5) as general, potential wildlife crossing locations: MP 283, 286, 289, 292, 295, 299, 301, and 303 (Figures 48 and 50).

During the final SR 260 Rim to Overgaard design process, a multi-agency, multi-disciplinary team (e.g., the Wildlife TAC) of engineers, biologists, project managers, and maintenance personnel could use this study's selected potential locations, obtain updated and additional information if needed, and then determine the final WCS types and locations.

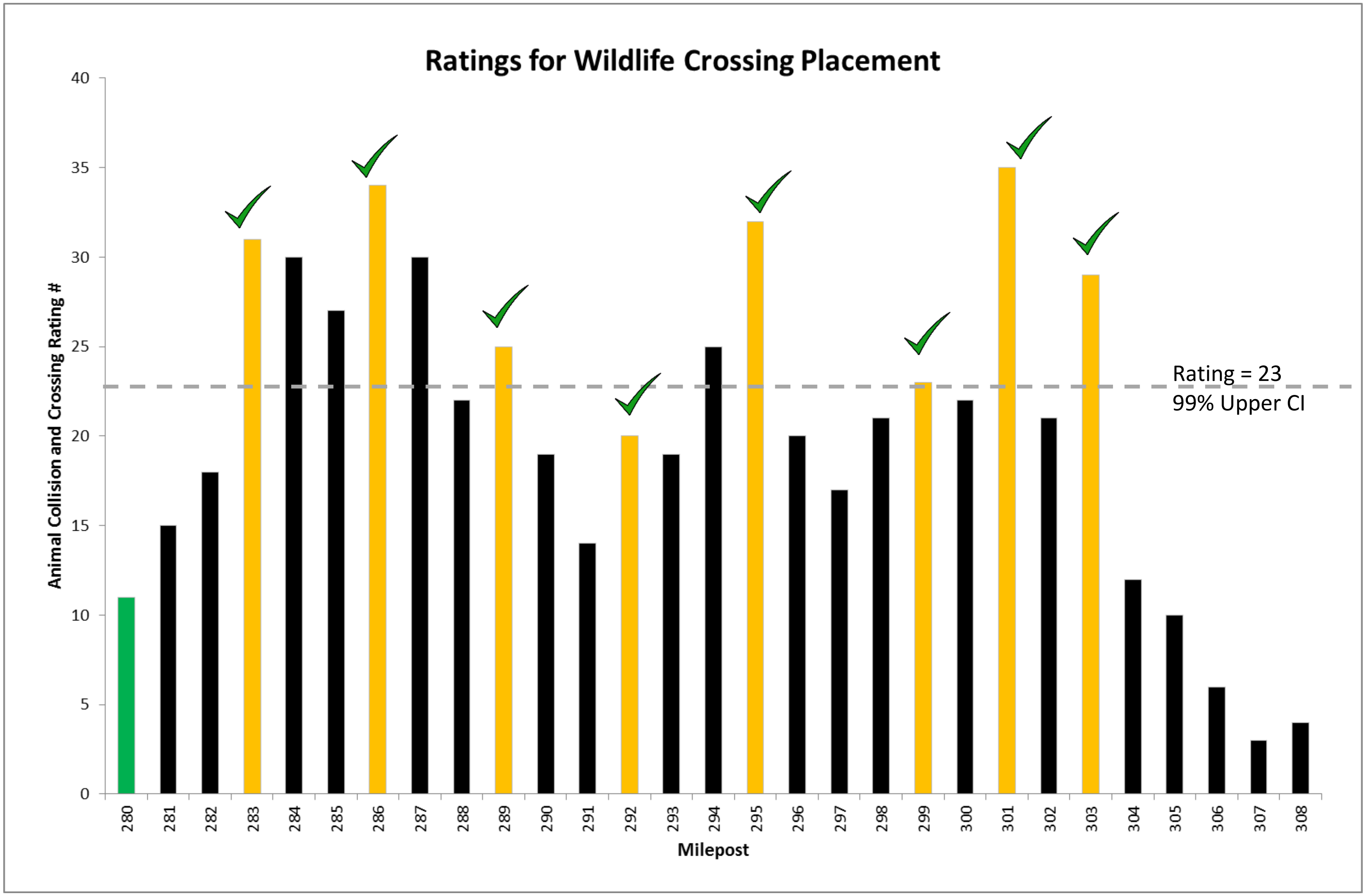


Figure 48. Potential Wildlife Crossing Placement on SR 260: Mogollon Rim to Overgaard (MP 280-308)

Overall Ratings Based on Upper 99 Percent Confidence Interval **(Dashed Line)** and Suitable WCS Spacing

Green Check Mark = Selected Wildlife Crossing Structure Locations; **Black Bar =** Areas not Selected for Future Mitigation

Green Bar = Existing Structure Suitable for Wildlife Passage; **Orange Bar =** Recommended Location for WCS

FENCING AND ESCAPE MECHANISM OPTIONS ALONG STATE ROUTE 260

Eight-foot-high exclusion fencing is a key element when using WCS to mitigate WVC and wildlife habitat fragmentation. The Payson-Heber FEIS and Overgaard-Show Low L/DCR specify that exclusion fencing will be installed and its location determined by ADOT, AGFD, and USFS. To develop preliminary exclusion fencing recommendations, the research team incorporated the research findings from multiple Arizona projects and considered SR 260's significantly high number of WVC incidents.

The fencing, also referred to as funnel-fencing, is intended to guide animals to crossing structures, where they may cross the roadway either over a wildlife overpass or under a roadway bridge. For example, without adequate funnel-fencing, the multiple SR 260 WCS west of the Rim were initially unsuccessful: WVCs increased and WCS use was minimal. However, after additional fencing was placed according to GPS movement data, WVCs decreased by 85 percent and WCS use by elk and deer increased significantly (Dodd et al. 2007c).

Gagnon et al. (2015) documented a 98 percent reduction in EVC and a more than 100 percent increase in existing structure use after funnel-fencing connected existing roadway structures. However, unconnected short funnel-fencing segments can be ineffective when animals follow the segment to the fence end and then cross the roadway there. Longer fencing segments that terminate at appropriate locations minimize such undirected crossings (Bellis and Graves 1978, Woods 1990, McCollister and van Manen 2010, Gulsby et al. 2011), contributing to fewer WVCs and greater WCS use (Huijser et al. 2016).

For the SR 260 Rim to Show Low reconstruction mitigation measures to be effective, connecting funnel-fencing between crossing structures will be necessary, as already recognized in the L/DCR (ADOT 2014). The fencing would be used to direct animals to wildlife crossing structures and large culverts and away from the ROW. In addition, lateral access roads that function as ROW access opportunities must be designed to minimize animal ROW entry, requiring either double cattle guards or gates. Animals that gain ROW entry will be trapped by the fence within the roadway corridor and will require a means of egress or escape. To this end, escape mechanisms should be placed at appropriate locations and intervals within the fence line. As already detailed in the L/DCR, escape mechanisms would be installed approximately every half mile. The FEIS for SR 260 from Payson to Heber/Overgaard suggested one-way exit gates and earthen ramps be incorporated into the fence line as escape mechanisms (FHWA 2000).

Fencing should terminate at logical locations: existing structures, cliffs, or straight road segments that allow motorists greater visual distance. The Wildlife Connectivity TAC was aware of these concerns and recommended in the L/DCR that the termini locations be verified by a biologist familiar with the SA (ADOT 2014).

Not only is permanent exclusionary fencing a concern, but the L/DCR also noted that during each construction phase of the SR 260 corridor improvement projects, exclusionary fencing may need to be installed beyond the construction area on a case-by-case basis, the fence installation being a joint adaptive management decision among the agencies involved: ADOT, FHWA, ASNF, AGFD, and the land owner/manager for that case. Figures 49 and 50 map this study's recommended locations of WCS and fencing.

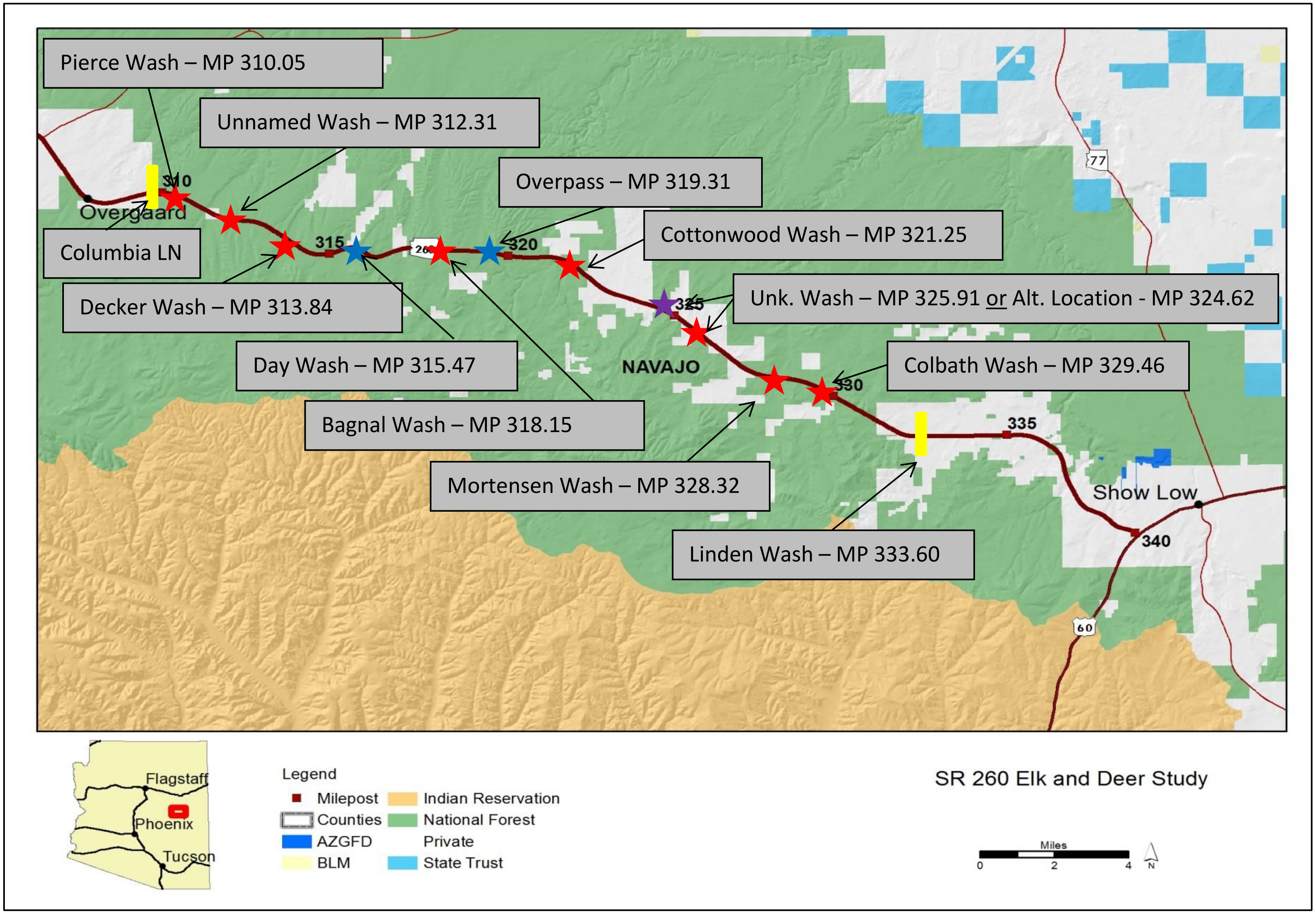


Figure 49. Recommended Specific Locations of Wildlife Crossings and Fencing from Overgaard to U.S. 60. Red and Blue Stars Mark Underpass, Overpass, and Alternate Locations, Respectively, and Yellow Bars Mark Proposed Fence Ends

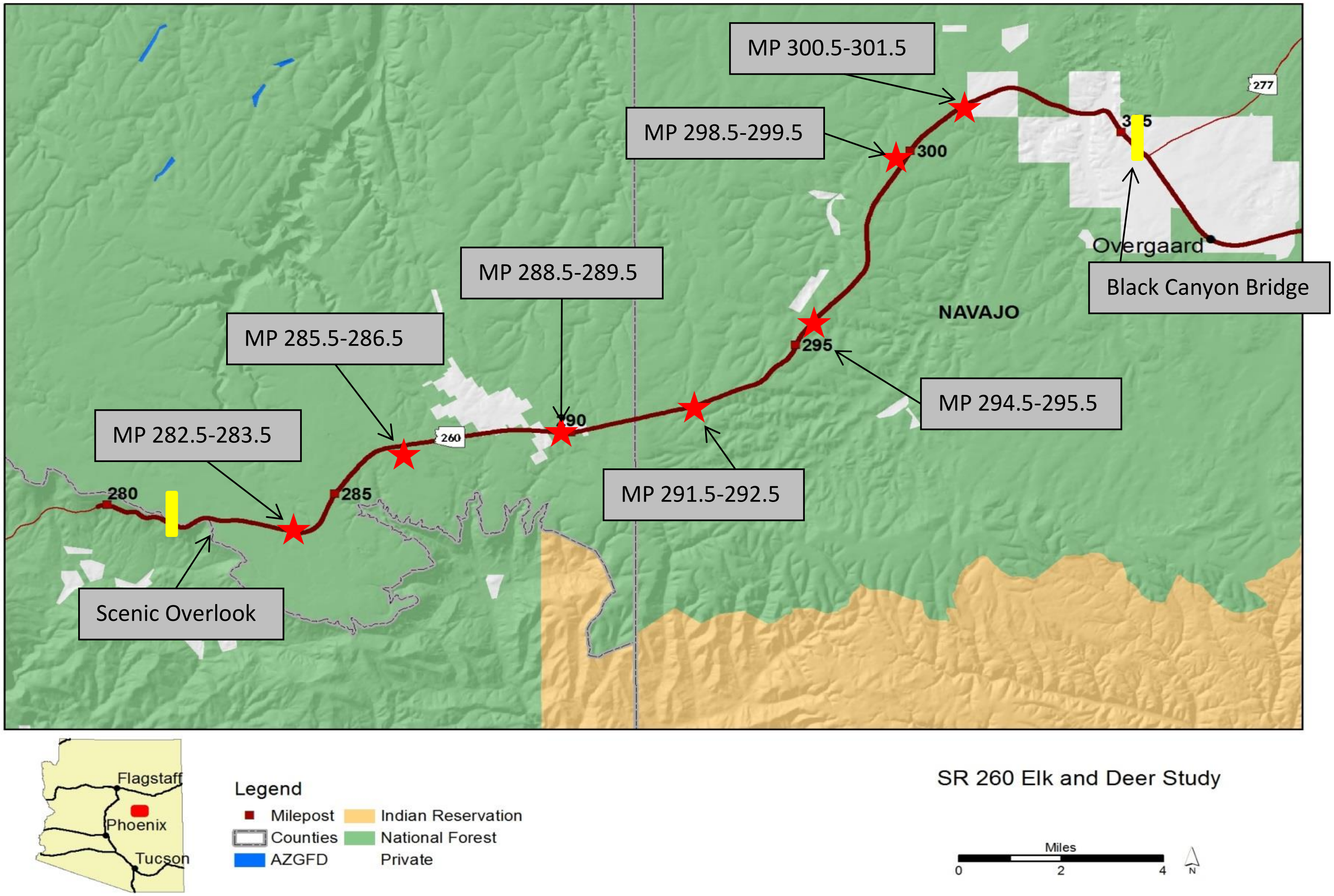


Figure 50. General Recommended One Mile Sections for Wildlife Crossings (Red Stars) and Fencing (Yellow Bars Indicate Fence Ends) from the Mogollon Rim to Heber. Locations Identified by the Research Team's Ratings. Specific Locations to be Determined in Final Design

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Wildlife dietary resource access and traditional, unfettered movement patterns are now impeded by roadways. As a result, wildlife occupy the areas adjacent to roads and cross roadways to access preferred or essential dietary resources (e.g., food and water) that fluctuate spatially and temporally and result in increased site-specific wildlife-vehicle interactions (Gunson et al. 2003, Dodd et al. 2005, Ng et al. 2008). In addition to dietary resources, wildlife mating and migration movement patterns also lead to temporal, locational increases in wildlife-vehicle interactions (Romin and Bissonette 1996, Sullivan et al. 2004, Bissonette and Rosa 2012, Sawyer et al. 2012, Sawyer et al. 2016). Since new and reconstructed roadways will be built and traffic volumes on those roadways will increase, wildlife-vehicle interactions, conflicts, and collisions along with wildlife habitat fragmentation will also increase unless effective mitigation measures are implemented.

Paramount to implementing effective mitigation measures is understanding site-specific wildlife movement patterns and how those patterns change spatially and temporally. Analyzing the GPS movement data collected from elk and deer along SR 260 built such an understanding. The research team's analysis indicated that SR 260 between the Rim and Show Low had multiple, site-specific, regularly used wildlife crossing locations—the most used area was near Heber's western boundary. Often, site-specific crossing areas are associated with riparian meadows (Manzo 2006, Dodd et al. 2007a) and the research team's analysis corroborated this association for the few riparian meadows within the area. For the other regularly used crossing locations, the research team believes that the 2002 Rodeo-Chediski wildfire created vegetation regrowth areas that function like riparian areas to attract wildlife (Bristow and Cunningham 2008). These vegetation regrowth areas provide substantial elk and deer food resources and are adjacent to or in close proximity to the majority of the SR 260 study area. The presence of this relatively new food source has likely resulted in more numerous and dispersed crossing locations. Areas void of this new resource and occupied by human development did not have regularly used crossing locations.

In addition, the research team found wildlife movement patterns to affect site-specific crossing areas. The SR 260 study area's western boundary is near the Rim, which migratory elk and deer use to access seasonal habitats. During the summer months, animals inhabit the SA and cross this section of SR 260 to access resources; during the winter, the animals in the western SA cross SR 260 to migrate to lower elevation habitat. As a result, the SA's western portion has fewer winter WVCs when compared to summer. The animals in the eastern SR 260 SA (Overgaard to Show Low) do not have the same migratory movement patterns. Elk and deer can migrate seasonally without having to cross the roadway, resulting in a more consistent, yearly WVC rate without seasonal variations.

Traffic volume fluctuations appeared to impact elk and deer movements the most. Elk and deer crossed the road less as traffic volumes increased and this crossing reduction was more pronounced for deer. This finding is consistent with other Arizona studies that found deer to be sensitive to traffic volume

(Dodd and Gagnon 2011). Also, regarding elk behavior, this study's findings corroborate that traffic volume increases tend to contribute to decreases in elk road crossings.

SR 260 traffic volume is a "deadly trap" for wildlife according to theoretical models (Iuell et al. 2003, Seiler 2003). A deadly trap occurs when traffic volumes are low enough for animals to attempt roadway crossings but high enough to decrease the odds that they will cross successfully (Figure 51). When traffic volumes are low, crossing animals are less likely to interact with vehicles. When traffic volumes are high, animals do not attempt to cross; the sequence of passing vehicles essentially creates a "moving fence" (Bellis and Graves 1978). The idea that the moving fence would ultimately eliminate animal crossings and WVCs has proved to be inaccurate according to Arizona research. I-17 and I-40 studies have found that a few animals still attempt to cross roadways with high traffic volumes but have a higher probability of being involved in a WVC (Jaeger et al. 2005). SR 260 rural traffic volumes are expected to increase to 10,000 AADT and will increase the likelihood of WVCs if proactive measures are not taken (ADOT 2014). In addition, the Rodeo-Chediski fire vegetation regrowth may entice more animals to attempt crossing the roadway despite traffic volumes.

WCS, as a proactive mitigation measure, have the potential to reduce WVCs and negate traffic volume effects on wildlife crossing the roadway corridor (Gagnon et al. 2007b, Gagnon et al. 2007c, Dodd and Gagnon 2011). The research team expects WCS to have this effect on SR 260 from the Rim to Show Low.

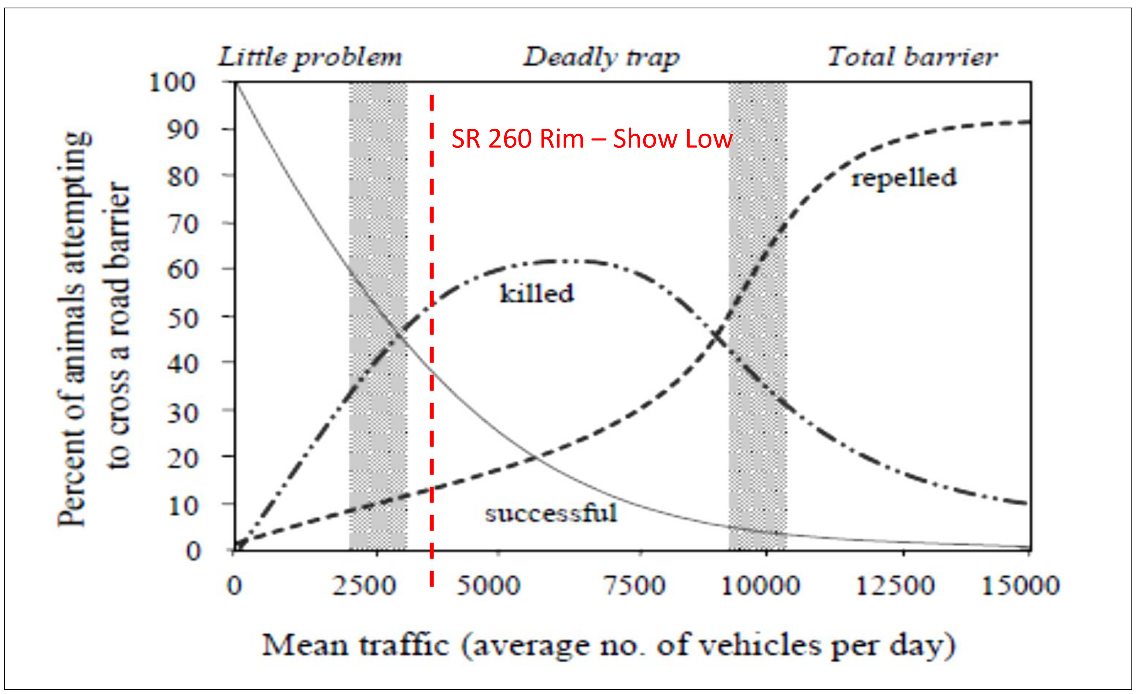


Figure 51. Conceptual Model Showing the Percent of Animals that Cross, Repelled, or Killed Along Roadways Versus Traffic Volume *(Source: Seiler 2003)* Overlaid with SR 260 Traffic Volume (Dashed Red Line)

RECOMMENDATIONS

The research team evaluated elk and deer GPS movement, WVC data, land ownership, and topography to locate WVC reduction mitigation measures that also maintain habitat connectivity along SR 260 from the Mogollon Rim (MP 280.0) to Show Low at U.S. 60 (MP 340.0).

WVCs along SR 260 are a significant roadway safety issue. The ongoing SR 260 L/DCR process and assessment represent ADOT's commitment to develop data-driven, comprehensive strategies for reducing WVC and maintaining wildlife connectivity. Such strategies lead to efficient roadway reconstruction planning, deliberate WCS and exclusion fence placement, and verifiable mitigation measures success.

Wildlife Crossing Structures and Fencing

The research team rated 60 1-mi SR 260 roadway segments in order to prioritize WCS placement, resulting in the recommendation of 10 WCS locations east of Overgaard (MP 309 – 340) and eight WCS locations west of Overgaard (MP 280 – 309). The 10 recommended locations from Overgaard east to Show Low took into account the preliminary suggestions from the Wildlife Connectivity TAC, but they marginally alter the L/DCR preliminary locations to allow for adequate structure spacing and to include additional important sites that were identified by this study. The eight recommended locations along SR 260 from the Rim to Overgaard were informed by the Payson—Heber FEIS (FHWA 2000). This study's recommendations along both sections of SR 260 are two to three miles apart; see Chapter 5 for location descriptions and discussion of determining factors.

- For work on SR 260 west of Overgaard to the Rim, it is suggested that ADOT form another multidisciplinary TAC, similar to the Wildlife Connectivity TAC formed for SR 260 Overgaard to U.S. 60. This future TAC could work to identify optimal, specific WCS locations within the prioritized SR 260 segments from this study.

Of the 10 locations east of Overgaard, two are suggested for construction of wildlife OPs, along with an alternative site for a possible third OP. Three of the recommended locations involve existing roadway structures (the bridges at Cottonwood Wash, Mortensen Wash, and Pierce Wash) that could function as dual-use wildlife/drainage structures. As a short-term strategy to reduce WVCs, ADOT could continue to "retrofit" such existing drainage structures. This strategy was successfully implemented on I-17 for elk (Gagnon et al. 2015). Because deer are less selective than elk when using structures to pass under roads, retrofitting existing structures requires that those structures selected are adequate to accommodate elk passage. If this approach is selected, it is recommended that ADOT consult with AGFD and ASNF for final recommendations. A post-construction retrofitting evaluation could verify the effectiveness of this short-term solution.

Part of this strategy is considering wildlife crossings and fencing as long-term solutions to mitigating WVCs and wildlife habitat fragmentation. This would mean linking WCS with 8 ft exclusion (ungulate-proof) fence to direct wildlife to viable crossings under the roadway. These measures have proven to reduce WVCs while maintaining habitat connectivity regardless of traffic volumes.

The team recommended such exclusion fencing for a majority of the SA outside of Heber, Overgaard, and Show Low. The research team advises against the use of several shorter unconnected fencing segments that would result in more wildlife ROW access opportunities. This is based on previous experience. The phased SR 260 reconstruction below the Rim resulted in segmented 8 ft ungulate-proof fencing that, in some instances, ended at locations that created an opportunity for animals to go around the fence; thus, elk and deer crossed SR 260 at the fence ends in concentrated numbers and increased WVC potentials until the fencing configuration was changed.

Fencing should terminate at logical locations: existing structures, cliffs, and straight road segments that allow motorists greater visual distance, and in some instances may require an animal activated detection system to alert motorists of wildlife presence. The research team agrees with the Wildlife Connectivity TAC's recommendations and suggests ADOT consult with biologists familiar with the area and elk behavior to ensure that the fencing is ended at logical termini, which may extend past the associated project limits.

- The research team recommends ADOT consider portable animal detection system installation just beyond the fence ends if logical fencing termini are not available. The systems could be moved to other project locations when the fencing is extended to appropriate termini.
- The research team recommends ADOT consider flashing silhouette signs at fence ends.

Overgaard—Show Low Fencing

The recommendation is to install continuous fencing from Overgaard's Columbia Lane east to approximately Linden Wash at MP 333.6. This fence passes through most high WVC segments and wildlife road crossings, and if the fence were extended to Fool Hollow Wash (MP 338.95), the remaining, lower WVC segment near Bagnal Wash (MP 337.5) would be included. If ADOT does stage fencing as per the L/DCR recommendation, the fencing would be erected on either side of the roadway simultaneously.

Mogollon Rim—Overgaard Fencing

For this segment of SR 260, the recommendation is to install continuous exclusion fencing from the Mogollon Rim (west of the scenic overlook) east to the Black Canyon Bridge's western abutments near Heber. In-line fence escape ramps would be installed approximately every half mile and doublewide cattle guards or other appropriate measures (e.g., gates) would be installed where the fence intersects lateral access roads. If construction is completed in sections or phases, the fencing should be erected on either side of the roadway simultaneously.

Fencing Installation and Maintenance

The use and maintenance of ADOT's standard 8 ft high ungulate-proof fencing is a proven, cost-effective approach to reducing WVCs. To minimize the long-term fencing maintenance costs related to water/flooding and tree damage repair, the fencing would be adjoined to WCS and culverts and ASNF would be consulted to remove trees that may fall on the fence. Previous discussions with ASNF staff during the L/DCR and EA processes indicated that they were willing to consider tree removal prior to fence installation and to reevaluate the need on a regular basis. Additionally, the fencing should be placed in locations that are easily accessible for yearly ADOT Maintenance fence checks and repairs.

- The research team recommends that the 8 ft ungulate-proof fencing limits include the areas identified in this report (Chapter 5). Fencing should connect all WCS and culverts larger than 24 inches to accommodate large and small wildlife and reduce fencing "wash out" maintenance.
- The research team recommends that ADOT Maintenance work with ASNF to identify and remove trees prior to fence construction and on a regular basis following construction. ASNF has expressed interest in these discussions, and tree removal will ensure fence integrity and reduce maintenance costs.
- The research team recommends yearly fence maintenance inspections to evaluate fence integrity and complement the ad hoc repairs made throughout the year.

Fencing Escape Mechanisms

While 8-ft-high exclusion fencing is a key element when using WCS to mitigate WVCs and maintain wildlife habitat connectivity, if animals breach the fence, measures that allow egress (e.g., escape ramps) are essential. In addition, proper measures should be implemented at lateral access roads, which can be wildlife ROW access points.

The research team agrees with the Wildlife Connectivity TAC's recommendations and suggests that escape ramps be installed every half mile, be constructed using retaining walls (not Gabion baskets), be 6 ft in height, and have a flat and unobstructed landing pad. Gates should be 8 ft high and cattle guards should be doublewide (two adjacent standard cattle guards requiring animals to jump farther to enter the ROW) unless appropriate alternatives are identified prior to final design.

Wildlife Movement and Collision Data Design Concept Study Process

With the ongoing SR 260 L/DCR process and assessment, the research team recommends that similar data-driven assessments be completed for Arizona roadways with WVC and wildlife permeability issues. When a roadway requires a Design-Build approach, the research team recommends that site-specific data collection, analysis, and evaluation become part of the Design-Build process. For these instances, wildlife can be fitted with GPS collars and real-time information and analysis can inform design decisions.

- The research team recommends GPS telemetry studies be conducted to ensure effective WCS and fencing locations. Funding these studies during the project scoping or the planning phase ensures the study's results and recommendation will be available during the project development process.

- The research team recommends that ADOT and partnering agencies collect and archive spatially accurate Arizona WVC data using an interagency mobile device application, or app; such an app was being tested by AGFD and ADOT as of 2017.. This app will enable the easy collection of more accurate baseline data; the data will enable the prioritization of WVC mitigation efforts, provide valuable information for future roadway planning and design, and provide a means for post-construction evaluation of mitigation measures.

Post-Construction Monitoring

Monitoring mitigation results will document their effectiveness in terms of any WVC reduction and continued habitat connectivity. Such documentation can then inform decisions on other roadways. Arizona mitigation monitoring, which began in 2000, has allowed ADOT to develop, implement, and defend its WVC and wildlife connectivity management decisions. Additionally, post-construction monitoring provides a means of informing adaptive management approaches to increase success of mitigation measures (Dodd et al. 2012a). From a mitigation perspective, SR 260 from Rim to Show Low is a unique area, and this uniqueness provides a learning opportunity that could impact future roadway projects and warrants a thorough post-construction evaluation:

- The research team recommends that ADOT fund scientifically sound, post-reconstruction monitoring to evaluate short- and long-term mitigation effects that can inform ongoing and future projects. The monitoring can further our knowledge and understanding of how effective mitigation measures are at reducing WVC and maintaining habitat connectivity.

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APPENDIX

Table 1. Ratings for One Mile Segments for Wildlife Crossing Structure Recommendations

Segments	Elk Crossing Rating	Deer Crossing Rating	AVC Rating	Human Activity Rating	Terain Rating	Land Ownersip Rating	Total Rating
280	1	0	1	6	0	3	11
281	3	0	3	6	0	3	15
282	5	1	3	6	0	3	18
283	11	1	9	6	1	3	31
284	9	0	9	6	3	3	30
285	11	0	6	6	1	3	27
286	11	1	12	6	1	3	34
287	7	1	12	6	1	3	30
288	5	0	9	6	1	1	22
289	7	1	9	6	1	1	25
290	5	0	6	6	1	1	19
291	1	0	3	6	1	3	14
292	1	0	9	6	1	3	20
293	3	0	6	6	1	3	19
294	11	1	3	6	1	3	25
295	9	1	12	6	1	3	32
296	3	1	6	6	1	3	20
297	3	1	3	6	1	3	17
298	7	1	3	6	1	3	21
299	9	1	3	6	1	3	23
300	11	3	3	1	1	3	22
301	11	5	12	3	1	3	35
302	11	1	6	1	1	1	21
303	11	0	9	3	3	3	29
304	0	1	9	0	1	1	12
305	0	5	3	0	1	1	10
306	0	1	3	0	1	1	6
307	0	0	1	0	1	1	3
308	1	0	1	0	1	1	4
309	1	0	1	3	1	1	7
310	3	0	6	6	6	3	24
311	3	0	3	3	3	3	15
312	7	1	12	3	1	3	27
313	9	1	12	6	6	3	37
314	3	1	12	6	6	3	31
315	3	1	6	6	6	3	25
316	9	0	9	6	6	3	33
317	5	0	6	6	6	3	26
318	7	0	6	6	6	3	28
319	5	0	12	6	6	3	32
320	11	0	12	6	1	3	33
321	7	0	12	6	6	3	34
322	7	0	3	1	1	3	15
323	5	0	1	1	1	1	9
324	3	0	1	1	3	1	9
325	5	0	9	1	1	1	17
326	11	3	9	1	3	1	28
327	11	1	6	1	1	1	21
328	9	5	9	3	6	3	35
329	1	1	12	3	3	3	23
330	3	0	9	6	1	3	22
331	5	0	6	3	1	3	18
332	3	0	6	0	3	1	13
333	3	0	3	0	1	1	8
334	1	0	1	0	3	1	6
335	0	0	1	0	1	1	3
336	1	0	3	0	3	1	8
337	1	0	6	0	3	1	11
338	0	0	1	0	1	1	3
339	0	0	1	0	3	1	5
340	0	0	1	0	1	1	3