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August 2021

US 160 Dry Creek Wildlife Study

APPLIED RESEARCH & INNOVATION BRANCH

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16. Abstract

The study monitored the effectiveness of the CDOT US 160 Dry Creek Wildlife Mitigation Project, located between Durango and Bayfield in Southwest of Colorado. Mitigation included a wildlife crossing structure at mile post (MP) 97.42, wildlife exclusion fence on both sides of US 160 from MP 97.05 to MP 97.82, and two EnviroGrid® Geocell treatments placed to deter wildlife from moving into the fenced mitigation area rights-of-way at the east fence ends. The primary objectives of this research were to quantitatively evaluate the effectiveness of the wildlife crossing structure and the EnviroGrid® Geocell treatments using Reconyx Professional cameras. A second objective was to conduct analyses of changes in WVC reported crashes between pre- and post-construction of the mitigation.

From August 14, 2018 through March 12, 2021 (934 camera days) there were 2,339 mule deer Total movements at the wildlife crossing structure and 2,066 mule deer Success movements through the wildlife crossing structure. The mule deer Success Rate was 88 percent, the Success per Camera Day was 2.2, and the Abundance was 2.5. While a camera on the north side of the right-of-way fence at the structure recorded 74 elk Total movements, no elk were detected by the structure entrance cameras. The fence end cameras documented 101 mule deer Total movements and 10 mule deer Interactive movements. There were six Repellency movements away from, and four Breach movements over the EnviroGrid® Geocell treatments.

Reported WVC crash rates (crashes/mile/year) decreased by 27 percent in the West Control section, decreased by 55 percent in the Mitigation section, and decreased by 24 percent in the East Control section. There was good evidence that the pre-construction crash rate was different from the post-construction crash rate in the Mitigation section (p = 0.11), good evidence that the crash rate change between pre- and post-construction in the West Control section was different than the crash rate change between pre- and post-construction in the Mitigation section (p = 0.12), and good evidence that the crash rate change between pre- and post-construction in the East Control section was different than the crash rate change between pre- and post-construction in the Mitigation section (p = 0.16).

Implementation

This wildlife crossing structure design works well for mule deer and can be replicated in other areas. The wildlife crossing structure did not work for elk during this study. EnviroGrid® Geocell future use may be warranted. The crash data analysis indicated that the current mitigation was effective and that additional mitigation measures (wildlife crossing structures and wildlife fence) are warranted both west and east of the current mitigation.

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EXECUTIVE SUMMARY

The US 160 Dry Creek Wildlife Mitigation Project, located between Durango and Bayfield in southwest Colorado, was completed by the Colorado Department of Transportation (CDOT) in 2016. It included a wildlife crossing structure at mile post (MP) 97.42, wildlife exclusion fence on both sides of US 160 from MP 97.05 to MP 97.82, and two treatments placed to deter wildlife from moving into the fenced mitigation area rights-of-way at the east fence ends (Figure 1). The fence end treatments utilized EnviroGrid® Geocell, a cellular soil confinement system. The goals of the mitigation were to provide connectivity by allowing elk, mule deer, and other wildlife species to easily move under US 160, and to reduce wildlife-vehicle collisions (WVC). The primary objectives of this research were to quantitatively evaluate the effectiveness of the wildlife crossing structure and the EnviroGrid® Geocell treatments. An additional objective was to conduct a Before-After-Control-Impact (BACI) analysis of the changes in WVC reported crash rates between pre- and post-construction of the mitigation.

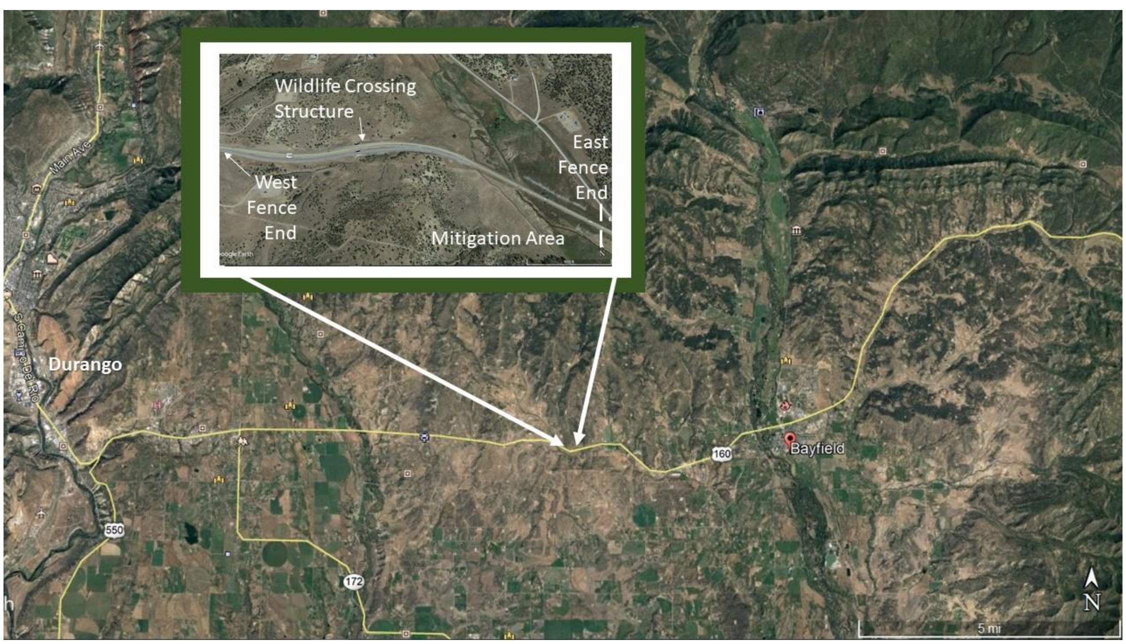

Figure 1. Study Area Map, East of Durango, and West of Bayfield Colorado on US 160.

Reconyx Professional cameras were used to monitor the entrances of the wildlife crossing structure, an area north of structure at the right-of-way fence (Wild Camera), and the EnviroGrid® Geocell treatments. The cameras recorded mule deer, elk, and other wildlife species movements and their behaviors. Wildlife movements and behaviors were categorized and tallied to quantitatively evaluate the effectiveness of the structure and the fence end treatments.

From August 14, 2018 through March 12, 2021 (934 camera days) there were 2,339 mule deer Total movements at the wildlife crossing structure and 2,066 mule deer Success movements through the wildlife crossing structure. The mule deer Success Rate was 88 percent, the Success per Camera Day was 2.2, and the Abundance was 2.5.

Elk were not recorded by the Structure Cameras at the wildlife crossing structure during the study. However, 74 elk movements were recorded just 130 feet from the structure at the Wild Camera. Elk have crossed US 160 near the wildlife crossing structure. Four WVC involving elk were reported near the structure, two during pre-construction and two during post-construction.

From April 29, 2019 through March 12, 2021, there were 91 mule deer Non-interactive movements and 10 Interactive movements at the EnviroGrid® Geocell treatments. There were four Breach movements and six Repellency movements. The Interactive Rate of Repellency was 60 percent.

Reported WVC crash rates (crashes/mile/year) decreased by 27 percent in the West Control section, decreased by 55 percent in the Mitigation section, and decreased by 24 percent in the East Control section. There was good evidence that the pre-construction crash rate was different from the post-construction crash rate in the Mitigation section ($p = 0.11$), good evidence that the crash rate change between pre- and post-construction in the West Control section was different than the crash rate change between pre- and post-construction in the Mitigation section ($p = 0.12$), and good evidence that the crash rate change between pre- and post-construction in the East Control section was different than the crash rate change between pre- and post-construction in the Mitigation section ($p = 0.16$). The crash data analysis indicated that the current mitigation was effective and that additional mitigation measures (wildlife crossing structures and wildlife fence) are warranted both west and east of the current mitigation.

Implementation Statement

The wildlife crossing structure worked well for mule deer during this study. The structure design and dimensions can be replicated and placed in other areas where mule deer are the target species for mitigation.

The wildlife crossing structure did not work for elk during this study. Potential adaptive management and future mitigation that target elk include baiting the wildlife crossing structure, extending the wildlife fence, and constructing additional wildlife crossing structures. The length of future wildlife crossing structures should be minimized.

EnviroGrid® Geocell future use may be warranted. Moderately effective EnviroGrid® Geocell treatments may be acceptable because of the high non-interactive rate observed in this study; ninety percent of the mule deer movements at the fence ends were non-interactive with the treatments. Thus, expensive fence end treatments rather than low-cost easily-installed EnviroGrid® Geocell treatments may not be reasonable or warranted.

The crash data analysis indicated that the current mitigation was effective and that additional mitigation measures (wildlife crossing structures and wildlife fence) are warranted both west and east of the current mitigation. This research supports the future use of wildlife crossing structures of similar design and dimensions and wildlife fence for mule deer by CDOT and other departments of transportation.

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INTRODUCTION

The US 160 Dry Creek Wildlife Mitigation Project, located between Durango and Bayfield in southwest Colorado, was completed by the Colorado Department of Transportation (CDOT) in 2016. It included a wildlife crossing structure at mile post (MP) 97.42, wildlife exclusion fence on both sides of US 160 from MP 97.05 to MP 97.82 (0.77 miles), and two treatments placed to deter wildlife from moving into the fenced mitigation area rights-of-way at the east fence ends (Figure 2). The fence end treatments utilized EnviroGrid® Geocell, a cellular soil confinement system. The goals of the mitigation were to provide connectivity by allowing elk, mule deer, and other wildlife species to easily move under US 160, and to reduce wildlife-vehicle collisions (WVC). The primary objectives of this research were to quantitatively evaluate the effectiveness of the wildlife crossing structure and the EnviroGrid® Geocell treatments. An additional objective was to conduct a Before-After-Control-Impact (BACI) analysis of the changes in WVC reported crash rates between pre- and post-construction of the mitigation.

Reconyx Professional cameras were used to monitor the entrances of the wildlife crossing structure, an area north of structure at the right-of-way fence (Wild Camera), and the EnviroGrid® Geocell treatments. The cameras recorded mule deer, elk, and other wildlife species movements and their behaviors. The cameras were triggered by motion and took pictures of large and small animals, day and night. Wildlife movements and behaviors were categorized and tallied to quantitatively evaluate the effectiveness of the structure and the fence end treatments.

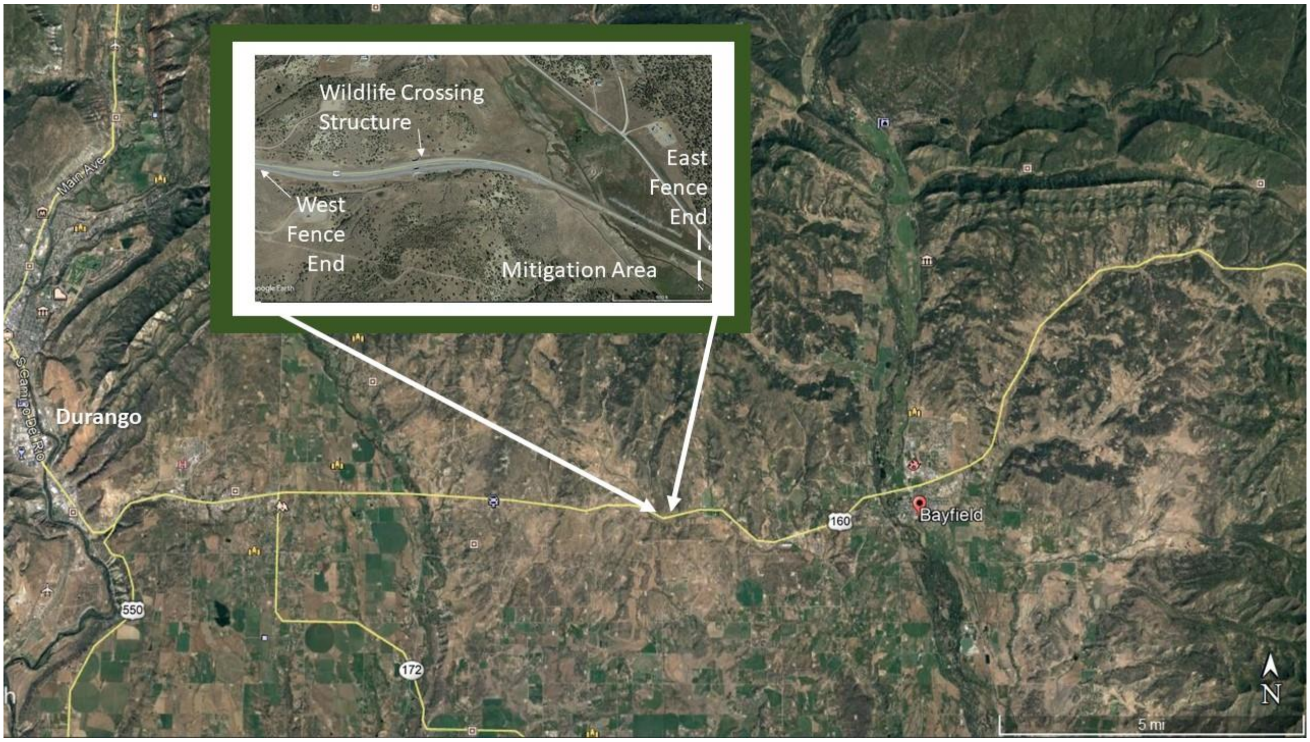

Figure 2. Study Area Map, East of Durango, and West of Bayfield Colorado on US 160.

The wildlife crossing structure was an underpass, and consisted of two concrete arches, each 13 feet high by 39 feet wide. The north arch was approximately 70 feet long and the south arch was approximately 52 feet long. The median opening between the arches was approximately 13 feet long (Figure 3). Total length was approximately 135 feet.

Figure 3. Monitored Wildlife Crossing Structure US 160 MP 97.42. The Monitoring Camera and Post at the South Entrance are in the Foreground. Cameras Faced the Entrances.

The EnviroGrid® Geocell was a flexible plastic material typically placed to prevent soil erosion. It was approximately six inches high, with leaf-shaped cells approximately eight inches by six inches (Figure 3). It was placed between the east fence end and the guard rail on both the north and south rights-of-way. The area of each treatment was approximately 10 feet by 30 feet.

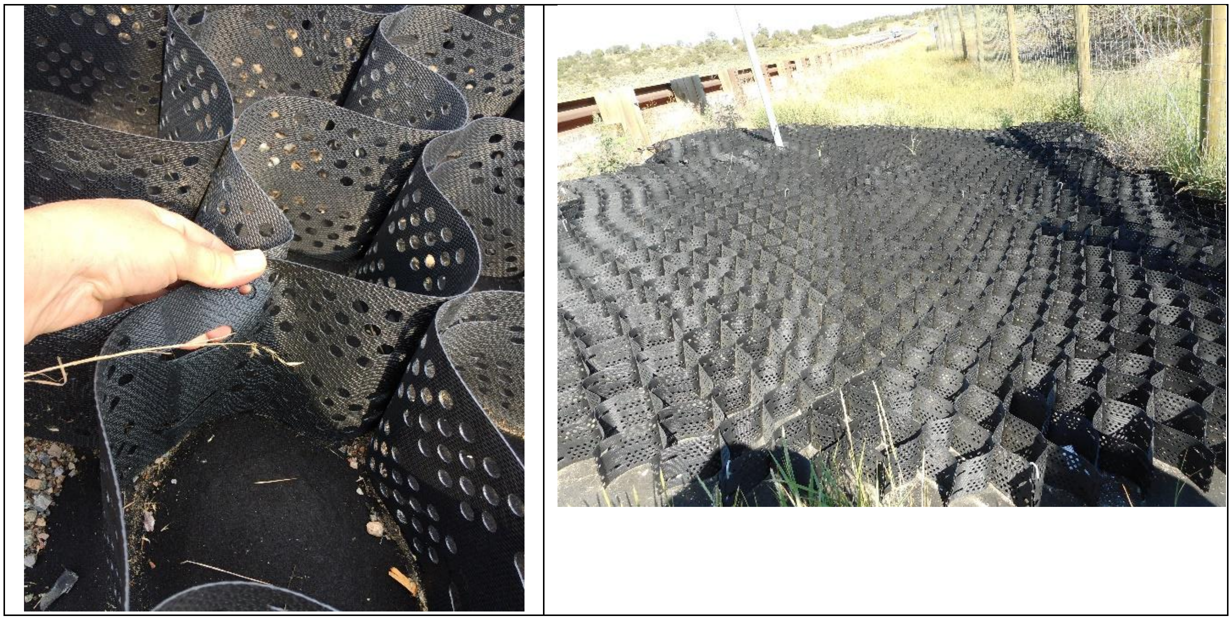

Figure 4. The EnviroGrid® Geocell Up Close (left), and In-Place at the East Fence End.

WILDLIFE CROSSING STRUCTURE

Methods

Three Reconyx PC800 cameras were installed on August 14, 2018. Two Structure Cameras were placed at the structure, one at each entrance (approximately 30 feet from the structure's openings, perpendicular to the northeast and southwest abutments, and aimed at the center of the openings). The Wild Camera was placed at the north right-of-way fence, approximately 130 feet from the center of the structure's north opening, aimed to the west-northwest. The purpose of the Wild Camera was to capture photos of wildlife beyond the right-of-way that may not have moved near the entrances of the wildlife crossing structure. The cameras were programed to take five pictures per trigger, rapid fire, with no delay. The three cameras were removed on March 12, 2021.

Unique individual mule deer movements at the wildlife crossing structure entrances were categorized and tallied based on the following definitions:

- Success = mule deer movements through the wildlife crossing structure,

- Repellency = movements when mule deer interacted with the structure (stepped in, smelled, moved toward, or looked at with apparent intention to cross) but failed to reach the other side, and
- Parallel = mule deer movements near the wildlife crossing structure entrances, without an interaction.

Success movements + Repellency movements + Parallel movements = Total movements for the wildlife crossing structure.

The following calculations were made for the wildlife crossing structure:

- Success Rate = Mule deer Success movements divided by Total movements,
- Rate of Repellency = Mule deer Repellency movements divided by Total movements,
- Parallel Rate = Mule deer Parallel movements divided by Total movements,
- Success per Camera Day = Mule deer Success movements divided by the number of days cameras were in operation, and
- Abundance = Total mule deer movements divided by the number of days cameras were in operation.

Mule deer Success movements recorded by both cameras were tallied as individual Success movements. Mule deer Repellency and Parallel movements were tallied at both ends of the structure. Direction of travel for mule deer Success movements was tallied beginning on July 5, 2019. For wildlife species other than mule deer, only Success movements were tallied. Humans and the number of human events observed in the structure were tallied. The durations of their visits were calculated and reported as human-minutes.

Mule deer movements recorded by the Wild Camera were not categorized and tallied, however, movements by other species were tallied.

Results

From August 14, 2018 through March 12, 2021 (934 camera days) there were 2,339 mule deer Total movements at the wildlife crossing structure and 2,066 mule deer Success movements through the wildlife crossing structure. The mule deer Success Rate was 88 percent, the Success per Camera Day was 2.2, and the Abundance was 2.5. Monthly mule deer Success movements and Total movements are presented in Figure 5. Monthly mule deer movements peaked in Spring and Fall. Success movements through the wildlife crossing structure were also made by the following species: gray fox (3), red fox (2), squirrel (4), rabbit (11), badger (4), raccoon (2), domestic cat (10), and coyote (3). Elk movements were not recorded by the Structure Cameras at the entrances to the wildlife crossing structure.

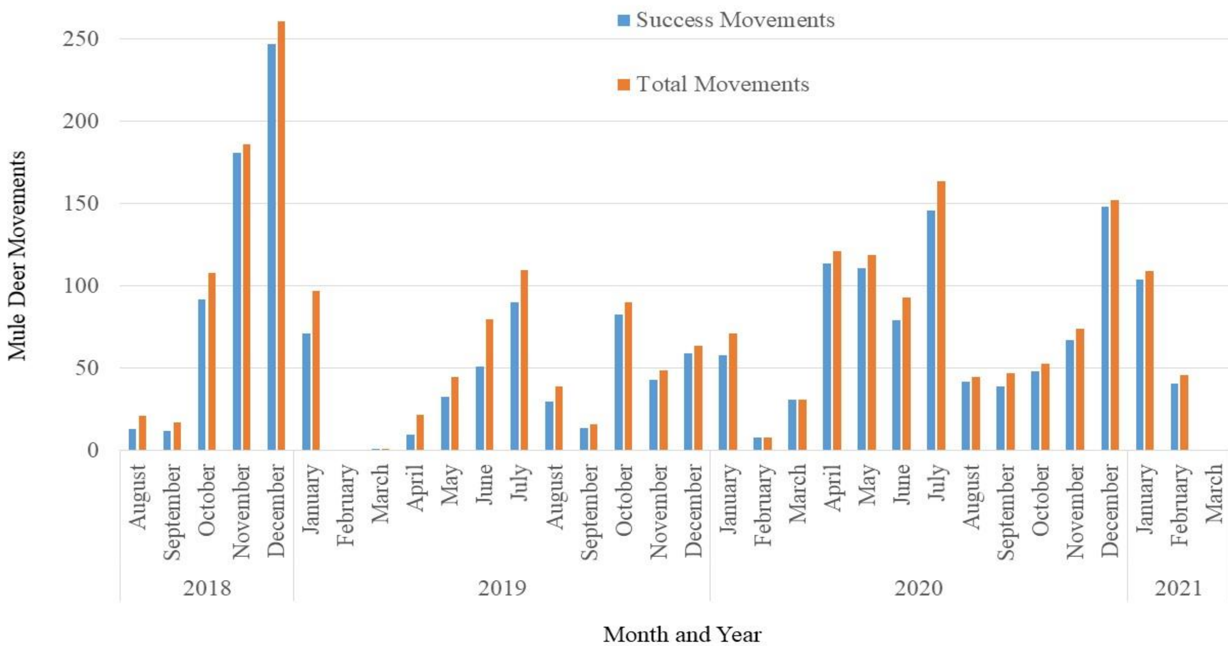

Figure 5. Monthly Mule Deer Success Movements and Total Movements at the Wildlife Crossing Structure, US 160 MP 97.42.

From July 5, 2019 through March 12, 2021 (609 camera days), there were 735 mule deer Success movements from north to south and 620 mule deer Success movements from south to north through the wildlife crossing structure, 54 percent and 46 percent, respectively.

From July 5, 2019 through March 12, 2021 (609 camera days), humans were observed in the structure during 15 separate events. Event durations ranged from one to 10 minutes. The number of humans at each event ranged from one to four. The total duration of the 15 events was 57 minutes. The total number of humans was 28 and number of human-minutes (number of humans at individual events multiplied by individual event durations) was 141. Events occurred in November 2019, and in March, April, May, and September 2020. On several occasions during the study, mule deer Success movements through the structure occurred within hours after humans left the structure.

The Wild Camera, at the north right-of-way fence on the north side of the wildlife crossing structure, from August 14, 2018 through March 12, 2021 (914 camera days), recorded: 74 elk movements, 39 coyote movements, 12 rabbit/hare movements, three fox movements, three domestic cat movements, and 12 domestic dog movements. Monthly elk movements at the Wild Camera are presented in Figure 6.

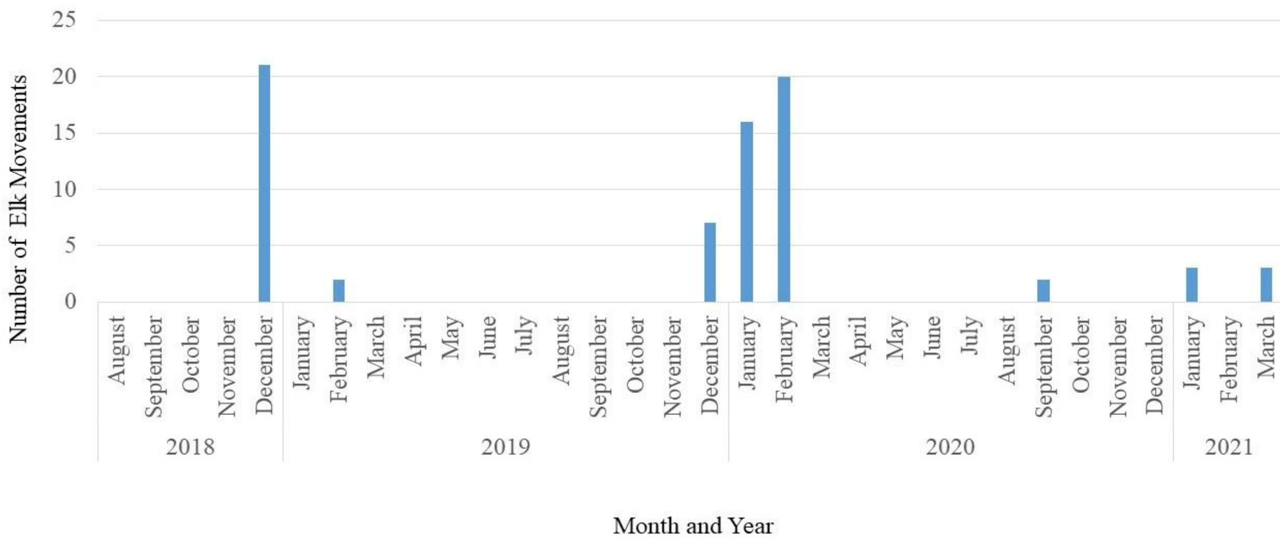

Figure 6. Monthly Elk Movements at the Wild Camera on the North Right-of-Way Fence, on the North Side of the Wildlife Crossing Structure, US 160 Mile Post 97.42.

Discussion

Mule Deer

The wildlife crossing structure was effective for mule deer based on the number of Success Movements per Camera Day (2.2) and the overall mule deer Success Rate (88 percent). The wildlife crossing structure was less effective than several highly effective wildlife crossing structures on

Colorado SH 9 (Kintsch et al. 2021). However, with 2,066 mule deer Success movements in 934 days and a Success Rate of 88 percent, the structure is comparable to many other effective structures studied by the research team in Utah (Cramer 2014, Cramer and Hamlin 2019a, b), and Montana (Cramer and Hamlin 2017). The structure appears to provide a high degree of connectivity for all genders and age classes of mule deer.

The mule deer Non-Interactive Success Rate (described below in the Fence Ends and EnviroGrid® Geocell Treatments section) of 67 percent over US 160 at the east fence ends can be used as a performance measure for the wildlife crossing structure. The structure's Success Rate of 88 percent exceeds this performance measure. In other words, mule deer are successfully moving through the wildlife crossing structure at a greater rate than they move over US 160 at the east fence ends.

While GPS collar data on the local mule deer herd does not exist, it appears that the mule deer herd consistently utilizing the wildlife crossing structure consists of approximately 30 individuals that are not highly migratory (although monthly movements peak in the Spring and the Fall and mule deer are absent during deep snow), with a home range that includes both sides of US 160 throughout most of the year. The herd size appears to increase in the fall when approximately 10 bucks join the herd.

Other Wildlife Species

Medium sized carnivores (fox, badger, raccoon, and coyote), squirrel, and rabbit utilized the structure. The occasional presence of humans in the structure did not appear to affect mule deer use of the structure.

Elk were not recorded by the Structure Cameras during the study. However, 74 elk movements were recorded just 130 feet from the structure at the Wild Camera. The elk recorded by the Wild Camera did not move toward or attempt to utilize the wildlife crossing structure. During the winter of 2020-2021, approximately 15 elk moved south over US 160 about one-quarter mile east of the mitigation (B. Weinmeister, personal communication). During pre-construction of the mitigation (2010-2015), two WVC crashes with elk were reported, one at MP 96.06 in 2015 and one at MP 96.2 in 2013. Two WVC crashes with elk were reported during post-construction (2016-2020), one at MP 98.5 and one at 98.6, both in 2019. Clearly, elk are motivated to cross US 160 near the wildlife crossing structure but are not motivated to approach or use the wildlife crossing structure. It is important to note that the wildlife fence in the mitigation section is only 0.77 miles in length. Three recently completed wildlife crossing structures in Colorado (US 285C, MP 146 and SH 9, MPs 132.5 and 136) have numerous elk success movements through the structures (M. Lawler, personal communication). These three structures have similar heights and widths to the US 160 structure; however, the US 160 structure's length is nearly twice as long. GPS collar data would provide additional information on elk migration, motivation, and home range in the area near the wildlife crossing structure. This information would benefit potential adaptive management of the current mitigation and guide potential future mitigation which may include baiting the wildlife crossing structure and extending the wildlife fence.

FENCE ENDS AND ENVIROGRID® GEOCELL TREATMENTS

Methods

Two Reconyx PC800 cameras were placed at the east fence ends at the start of the study in August of 2018, one on each side of US 160 to monitor wildlife movements at the fence ends and the EnviroGrid® Geocell treatments. These fence end cameras were stolen and subsequently replaced with two PC850 cameras on April 29, 2019. Cameras were aimed at the east sides of the EnviroGrid® Geocell treatments. The cameras were programed to take five pictures per trigger, rapid fire, with no delay. The cameras were removed on March 12, 2021.

Unique individual mule deer movements at the fence ends were divided into Non-interactive and Interactive movements, relative to the EnviroGrid® Geocell. Interactive movements were defined as mule deer looking at, moving toward, stepping on or through, or smelling the EnviroGrid® Geocell.

Non-interactive movements were categorized and tallied based on the following definitions:

- Success = mule deer movements over US 160,
- Repellency = mule deer movements toward US 160 with apparent intention to cross, but failed to reach the other side, and
- Parallel = mule deer movements parallel to US 160.

Interactive movements were categorized and tallied based on the following definitions:

- Breach = mule deer movements across the EnviroGrid® Geocell treatments from east to west, and
- Repellency = mule deer movements away from the EnviroGrid® Geocell treatments after interacting with them on their east sides.

Non-interactive movements + Interactive movements = Total movements.

The following mule deer rates were calculated for both fence end cameras combined:

- Non-Interactive Rate = Non-interactive movements divided by Total movements,
- Interactive Rate = Interactive movements divided by Total movements,
- Interactive Breach Rate = Breach movements divided by Interactive movements,
- Interactive Rate of Repellency = Repellency movements divided by Interactive movements,
- Non-interactive Success Rate = Success movements over US 160 divided by Non-interactive movements.

Mule deer Success movements recorded by both cameras were tallied as individual Success movements. Escape movements over the EnviroGrid® Geocell from the mitigated right-of-way were tallied but not included in Total movements because the cameras were not positioned to observe mule deer movements and behaviors at the west side (inside the Right-of-Way) of the EnviroGrid® Geocell treatments. For other wildlife species, movements were categorized and tallied.

Results

From April 29, 2019 through March 12, 2021, there were 91 Non-interactive movements and 10 Interactive movements (101 Total movements) by mule deer at the two fence end cameras (570 camera days at the north camera and 599 camera days at the south camera). Non-interactive movements included 61 Success movements, six Repellency movements, and 24 Parallel movements. Interactive movements included four Breach movements over the EnviroGrid® Geocell and six Repellency movements away from the EnviroGrid® Geocell. The Non-interactive rate was 90 percent (91 Non-interactive movements divided by 101 Total movements). The Interactive rate was 10 percent (10 Interactive movements divided by 101 Total movements).

For mule deer at both EnviroGrid® Geocell treatments, the Interactive Breach Rate was 40 percent (four Breach movements divided by 10 Interactive movements) and the Interactive Rate of Repellency was 60 percent (six Repellency movements divided by 10 Interactive movements).

The mule deer Non-Interactive Success Rate over US 160 was 67 percent (61 success movements divided by 91 non-interactive movements). This rate is very similar to success rates for mule deer, white-tailed deer, and elk over highways in Montana (Cramer and Hamlin 2017) and Utah (Cramer and Hamlin 2019a).

Mule deer escaped from the fenced mitigated area by moving from west to east over the EnviroGrid® Geocell treatments on four occasions (three escape movements at the north EnviroGrid® Geocell and one escape movement at the south EnviroGrid® Geocell).

Movements by other wildlife species included: coyote (three success movements over US 160, one parallel movement), fox (three success movements over US 160), bobcat (one EnviroGrid® Geocell breach movement), and raccoon (one success movement over US 160, six EnviroGrid® Geocell breach movements, and one escape movement over the EnviroGrid® Geocell).

Discussion

The EnviroGrid® Geocell treatments appear to be moderately effective at preventing mule deer from moving into the US 160 right-of-way based on the mule deer Interactive Rate of Repellency of 60 percent (permeability 40 percent). However, with just 10 mule deer Interactive movements, the small sample size precludes a definitive evaluation. The actual permeability of the EnviroGrid® Geocell treatments is probably higher based on the four recorded Escape movements. Again, these four Escape movements were not included in rate calculations because the fence end cameras did not record mule deer movements and behaviors on the west side of the EnviroGrid® Geocell treatments. We assume that mule deer were highly motivated to escape from the mitigated area over the EnviroGrid® Geocell, and that potential escape-repellency movements did not occur. If true, the actual permeability of the EnviroGrid® Geocell treatments could be as high as 57 percent (four Breach movements + four Escape movements divided by 14 Interactive movements). This is not necessarily a negative characteristic of the EnviroGrid® Geocell because we want mule deer to be able to easily escape the mitigation area. Since the cost is low, further use of EnviroGrid® Geocell may still be warranted even if the actual permeability is 57 percent rather than the observed 40 percent. In addition, moderately effective EnviroGrid® Geocell treatments may be acceptable because of the high Non-Interactive rate; ninety percent of the mule deer movements at the fence ends were Non-interactive with the treatments. Thus, expensive fence end treatments rather than EnviroGrid® Geocell treatments may not be reasonable or warranted.

REPORTED WVC CRASH DATA ANALYSIS

Methods

Reported WVC crash data during pre- and post-construction from MP 96.05 to MP 98.82 (2.77 miles) were received from CDOT and are presented in Table 1. These data were used to conduct a Before-After-Control-Impact (BACI) analysis of reported WVC crash rate changes within the mitigation and control sections during pre-construction and post-construction. The pre-construction period was June 10, 2010 through June 10, 2015 (5.0 years). The post-construction period was November 10, 2016 through June 30, 2020 (3.64 years). The west fence end was at MP 97.05, the wildlife crossing structure was at MP 97.42, and the east fence end was at MP 97.82. Crashes near the two fence ends (MPs 97.03, 97.1, 97.8, and 97.9) were not included in the analysis.

Table 1. Reported Wildlife-Vehicle Collision Crash Data During Pre- and Post-Construction from MP 96.06 to MP 98.80 Received from CDOT. **** = Data Not Included in Analysis***

	Milepost	Pre-Construction 06/10/2010 - 6/10/2015	Post-Construction 11/10/2016 - 6/30/2020
	96.06	2	0
	96.1	2	0
	96.17	1	0
	96.2	5	1
	96.22	0	1
	96.3	3	1
	96.45	0	1
	96.5	1	2
	96.55	0	1
	96.6	0	1
	96.7	1	0
	96.8	1	1
	96.9	0	1
	97.0	5	1
	97.03*	0	1
West Fence End	97.05		
	97.1*	0	2
	97.25	1	0
	97.3	2	1
	97.4	1	1
Wildlife Crossing Structure	97.42		
	97.5	1	0
	97.6	1	0
	97.7	3	1
	97.8*	1	2
East Fence End	97.82		
	97.9*	2	5
	98.0	2	2
	98.03	0	1
	98.05	0	1
	98.1	1	1
	98.2	0	1
	98.3	2	0
	98.4	4	1
	98.5	3	1
	98.6	5	2
	98.7	2	0
	98.8	1	1

Crashes were grouped into three sections:
West Control = crashes from MP 96.05 to 97.0 (0.95 miles),
Mitigation = crashes from MP 97.25 to 97.7 (0.45 miles), and
East Control = crashes from MP 98.0 to 98.82 (0.82 miles).

Pre-construction and post-construction crash rates (crashes/mile/year) were calculated for each of the three sections. The changes in crash rates between pre-construction and post-construction were then calculated for each of the three sections. The T.TEST function in Excel 2015 was utilized to test the following three null hypotheses:

H_0 #1: Pre-construction crash rate = post-construction crash rate in Mitigation section.
This hypothesis compared the pre- and post-construction crash rates in the Mitigation section;

H_0 #2: Crash rate change between pre- and post-construction in the West Control section = Crash rate change between pre- and post-construction in the Mitigation section; and

H_0 #3: Crash rate change between pre- and post-construction in the East Control section = Crash rate change between pre- and post-construction in the Mitigation section.

These latter two hypotheses compared changes between pre- and post-construction crash rates in the Mitigation and adjacent Control sections.

Results

Table 2 displays reported WVC crash rates (crashes/mile/year) during pre-construction and post-construction periods and changes in crash rates between pre-construction and post-construction at each of the three sections of US 160. The West Control section crash rate decreased by 27 percent, the Mitigation section crash rate decreased by 55 percent, and the East Control section crash rate decreased by 24 percent, between pre-construction and post-construction.

Table 2. Reported Wildlife-Vehicle Collision Crash Rates (Crashes/Mile/Year) in Three Sections of US 160 during Pre-construction and Post-construction and Changes in Crash Rates.

Time Period	West Control	Mitigation	East Control
Pre-construction	4.4	4.0	4.9
Post-construction	3.2	1.8	3.7
	Change = -1.2	Change = -2.2	Change = -1.2

For H_0 #1 (4.0 = 1.8), there was good evidence that the pre-construction crash rate was different from the post-construction crash rate in the Mitigation section ($p = 0.11$).

For H_0 #2 (-1.2 = -2.2), there was good evidence that the crash rate change between pre- and post-construction in the West Control section was different than the crash rate change between pre- and post-construction in the Mitigation section ($p = 0.12$). For H_0 #3 (-1.2 = -2.2), there was good evidence that the crash rate change between pre- and post-construction in the East Control section was different than the crash rate change between pre- and post-construction in the Mitigation section ($p = 0.16$).

Discussion

A thorough evaluation of the effectiveness of a wildlife mitigation project includes Before-After-Control-Impact analyses of reported WVC crash rate changes within the mitigation and control sections during pre-construction and post-construction. BACI analyses control for variables that may change during a study. These variables include traffic volume, mule deer population numbers, and other landscape-scale variables that directly affect crash rates. Traffic volume steadily increased during the study (M. Lawler, personal communication).

The BACI analysis comparing the changes in crash rates between pre- and post-construction for the Mitigation and West and East Control sections resulted in *p*-values of 0.12 and 0.16, respectively. These p-values are the probabilities that the observed effects (changes between pre- and post-construction crash rates being different between mitigation and controls) were due to random chance, given the null hypothesis is true. We prefer to let the reader choose the amount of random chance with which they are comfortable. This choice is arbitrary; many readers choose *p*-values of 0.05 or less to be statistically significant and to reject null hypotheses.

Crashes near the fence ends increased during post-construction, particularly at the east fence end (MP 97.9, Table 1). Control sections, if they are true control sections, and the evaluation of the mitigation should not be influenced by fence end crashes. In addition, the exact location (inside or outside of the mitigation) of crashes can be ambiguous when most crashes were reported to the one-tenth of a mile. Thus, crashes at MPs 97.03, 97.1, 97.8, and 97.9 were not included in the analysis (Table 1).

The decrease in crash rates between pre- and post-construction in the Mitigation section and the post-construction increase in crashes just beyond the fence ends in this study were similar to the results from the US 89 Kanab-Paunsaugunt (Cramer and Hamlin 2019a) and the US 191 Monticello (Cramer and Hamlin 2019b) mitigation research projects in Utah.

The crash data analysis indicated that additional mitigation measures (wildlife crossing structures and wildlife fence) are warranted both west and east of the current mitigation. In this study, crash rates in both control sections decreased by 1.2 crashes/mile/year, between pre- and post-construction. However, when the fence end crashes at MPs 97.03 and 97.9 were included in the crash analysis, crash rates decreased by 0.9 crashes/mile/year in the west end section (MP 96.05 to MP 97.05) and decreased by only 0.004 crashes/mile/year in the east end section (MP 97.82 to MP 98.82), between pre- and post-construction. The post-construction crash rate of 3.7 crashes/mile/year in the East Control section is similar to the pre-construction crash rate of 4.0 crashes/mile/year in the Mitigation Section. In addition, pre-construction crash rates in both Control sections (4.4 crashes/mile/year in the West Control section and 4.9 crashes/mile/year in the East Control section) were higher than the pre-construction crash rate in the Mitigation section (4.0 crashes/mile/year).

CONCLUSIONS AND RECOMMENDATIONS

The wildlife crossing structure was effective for mule deer based on the number of Success Movements per Camera Day (2.2) and the overall mule deer Success Rate (88 percent). The structure appears to provide a high degree of connectivity for all genders and age classes of mule deer. The structure's design and dimensions can be replicated in other areas where mule deer are the target species for mitigation. Elk were not recorded by the Structure Cameras during the study. Seventy-four elk movements were recorded by the Wild Camera; however, elk did not move toward or attempt to utilize the wildlife crossing structure. Thus, we can not make recommendations concerning the utility of the wildlife crossing structure's design and dimensions for elk. Potential adaptive management and future mitigation that target elk include baiting the wildlife crossing structure, extending the wildlife fence, and constructing additional wildlife crossing structures. The length of future wildlife crossing structures should be minimized. We recommend continued research and monitoring of wildlife crossing structures.

The EnviroGrid® Geocell treatments appear to be moderately effective at preventing mule deer from moving into the US 160 right-of-way based on the mule deer Interactive Rate of Repellency of 60 percent. EnviroGrid® Geocell future use may be warranted. Moderately effective EnviroGrid® Geocell treatments may be acceptable because of the high non-interactive rate observed in this study; ninety percent of the mule deer movements at the fence ends were non-interactive with the treatments. Thus, expensive fence end treatments rather than low-cost easily-installed EnviroGrid® Geocell treatments may not be reasonable or warranted.

The crash data analysis indicated that the current mitigation was effective and that additional mitigation measures (wildlife crossing structures and wildlife fence) are warranted both west and east of the current mitigation.

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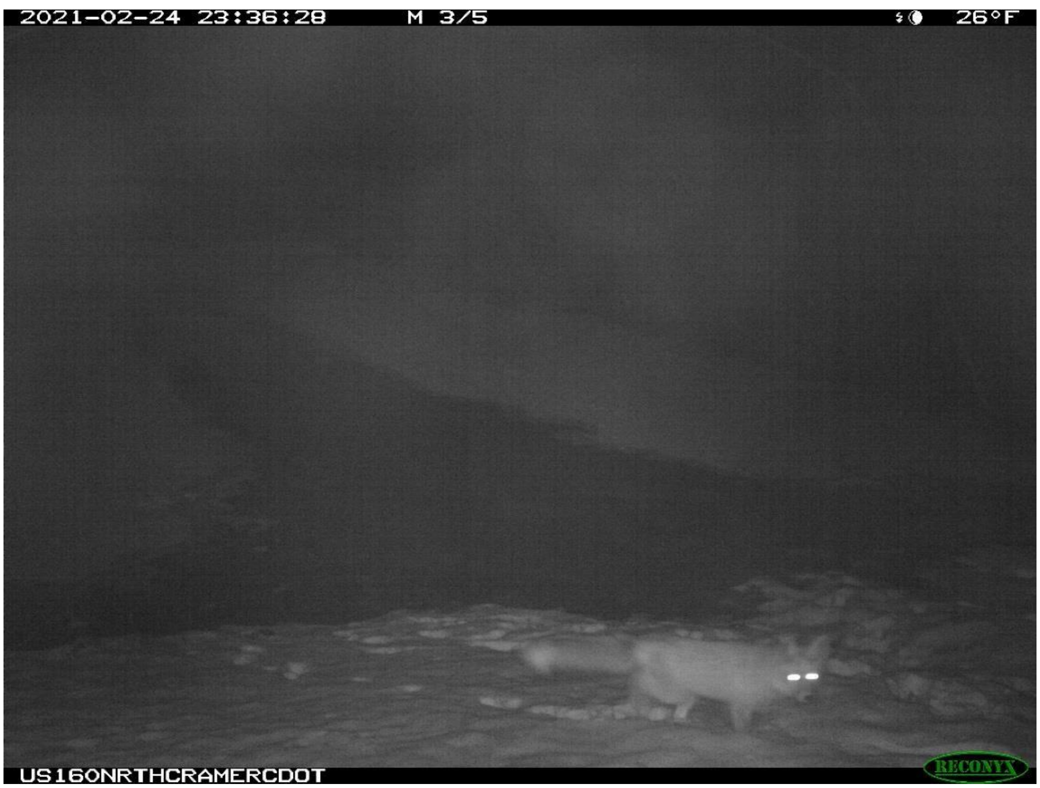
SELECT PHOTOGRAPHS FROM THE STUDY

Mule Deer success movements through the wildlife crossing structure.

Mule Deer success movements through the wildlife crossing structure.

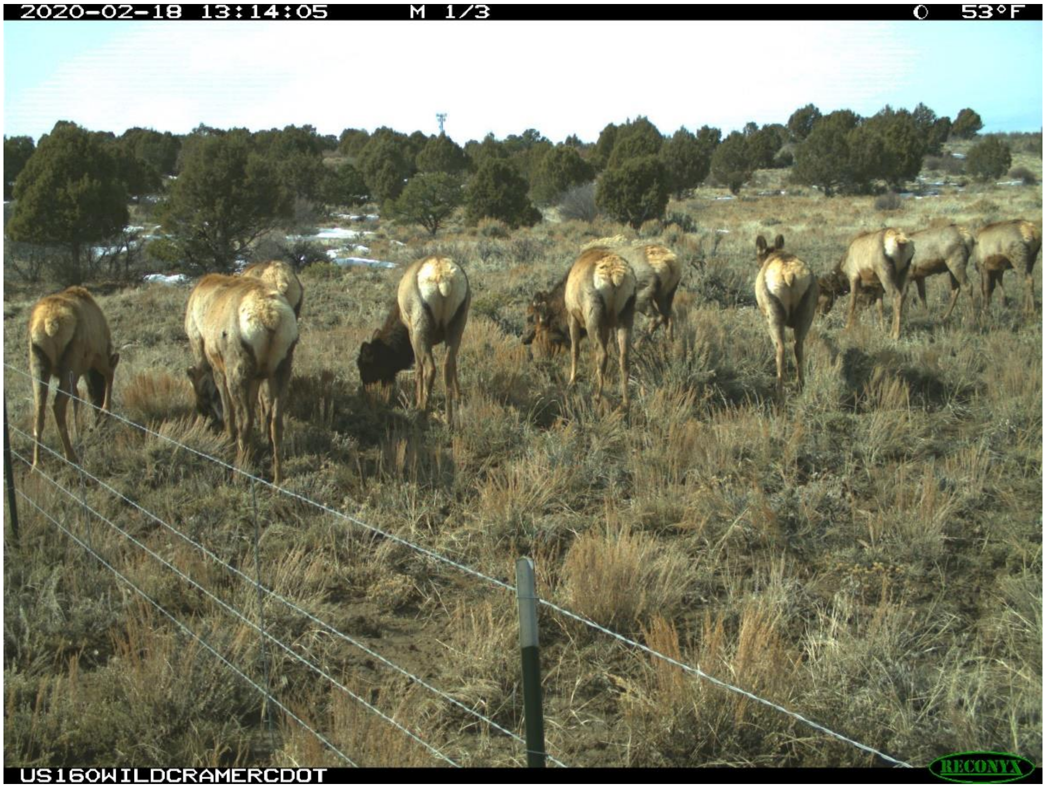
Mule Deer does brought fawns through the structure.



Red Fox success movement through the wildlife crossing structure.

Coyote success movement through the wildlife crossing structure.

Elk at the wild camera.



Herd of elk at wild camera, grazing outside of the right-of-way.

Mule deer success movement over US 160 at the EnviroGrid® Geocell treatment, north fence-end camera, non-interactive movement.

A mule walking over the EnviroGrid treatment to escape the Right-of-Way fenced area.

Bobcat movement at the EnviroGrid® Geocell treatment, south fence-end camera.

Raccoon success movement over US 160 at the EnviroGrid® Geocell treatment, south fence-end camera, non-interactive movement.