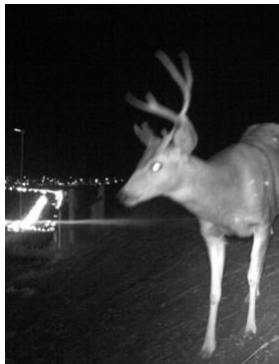




**COLORADO**  
Department of Transportation

Study Managed by CDOT Region 1

# US Highway 6 Wildlife-Highway Mitigation Assessment



Julia Kintsch, ECO-resolutions

Report No. CDOT-2020-14  
November 2020

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16. Abstract Wildlife-related collisions on US 6 are a persistent threat to driver safety on U.S. Highway 6 (US 6) along the west side of the City of Golden. In 2011, the Colorado Department of Transportation completed the installation of an at-grade crosswalk and associated wildlife fencing along 1.4 miles of US 6. Elk, deer, and other wildlife have since learned the location of the crosswalk to move across US 6. Yet, wildlife-vehicle collisions have continued to occur. This report reviews the circumstances leading to the installation of the at-grade crosswalk; evaluates the effectiveness of the mitigation in terms of wildlife-vehicle collision rates and wildlife movements at the at-grade crosswalk; and documents the processes through which CDOT and its partners assessed other mitigation alternatives and determined the need for a wildlife crossing structure in lieu of the existing at-grade crosswalk.  Implementation This report recommends removing the at-grade crosswalk and constructing a wildlife underpass at milepost 273.4 to reduce incidence of wildlife-vehicle collisions on US 6. In 2016, the City of Golden in coordination with CDOT received \$500,000 in grant funding to initiate design and environmental review for a wildlife crossing structure to replace the at-grade crosswalk. Final design (Final Office Review, equivalent to 85-90% design) was completed in Fall 2020. While construction funding has not been identified, the project partners remain committed to enhancing safety for motorists and wildlife on US 6.					
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## Executive Summary

Wildlife-related collisions on US 6 are a persistent threat to driver safety on U.S. Highway 6 (US 6) along the west side of the City of Golden. In 2011, the Colorado Department of Transportation completed the installation of an at-grade crosswalk and associated wildlife fencing along 1.4 miles of US 6. Elk, deer, and other wildlife have since learned the location of the crosswalk to move across US 6. Yet, wildlife-vehicle collisions (WVC) have continued to occur.

Elk movements across US 6 between 19<sup>th</sup> Street and Heritage Road (milepost [MP] 272.6 – 273.9) increased markedly following the construction of the Fossil Trace Golf Course in 2002 on the site of a former clay mine on the east side of the highway. Notably, elk-vehicle collisions on US 6 are uncommon outside of this 1.4-mile long segment, north of 19<sup>th</sup> Street or south of Heritage Road, indicating that elk movements across US 6 are motivated by the availability of winter forage around the golf course. In contrast, deer are known to cross a broader segment of US 6 and move further east to the open spaces on North and South Table Mountains, and deer-vehicle collisions have also been recorded north to the US 93 junction and beyond both prior to and following the construction of the golf course.

In addition to the shifts in WVC following the construction of the golf course on the former clay mine in 2002, there have been two additional events that have led to both spatial and temporal changes in WVC patterns along this segment of US 6, 1) the installation of the at-grade crosswalk in late 2010/early 2011, and 2) the construction of the 19<sup>th</sup> Street interchange, which was completed in mid-2017. Prior to the at-grade crosswalk, elk-vehicle collisions averaged 9.8 reported accidents each year (2003-2010). Post-mitigation, elk-vehicle collisions decreased to an average of 6.4 elk-vehicle collisions each year from 2012 through May 2017, when the construction of the 19<sup>th</sup> Street interchange was completed. A similar pattern is evident when consider WVC with all species – prior to the at-grade crosswalk there were an annual average of 14.5 WVC, which decreased to an average of 11.8 WVC per year from 2012 through May 2017. At this level, the rate of WVC are still higher than the threshold of 5.1 WVC per mile per year at which wildlife crossing structures are considered cost-effective with net public benefits (Huijser et al. 2009).

This report reviews the circumstances leading to the installation of the at-grade crosswalk; evaluates the effectiveness of the mitigation in terms of WVC rates and wildlife movements at the at-grade crosswalk; examines shifts in wildlife activity at the crosswalk over time, particularly due to the construction of the 19<sup>th</sup> Street grade-separated interchange and adjustments to the at-grade crosswalk system; and documents the processes through which CDOT and its partners assessed other mitigation alternatives and determined the need for a wildlife crossing structure in lieu of the existing at-grade crosswalk.

## **Implementation Statement**

This report recommends removing the at-grade crosswalk and constructing a wildlife underpass at MP 273.4 to reduce incidence of WVC on US 6. In 2016, the City of Golden in coordination with CDOT received \$500,000 in grant funding to initiate design and environmental review for a wildlife crossing structure to replace the at-grade crosswalk. Final design (Final Office Review, equivalent to 85-90% design) was completed in Fall 2020. While construction funding has not been identified, the project partners remain committed to enhancing safety for motorists and wildlife on US 6.

## Table of Contents

<b>Introduction</b>	<b>1</b>
<b>Site Description</b>	<b>3</b>
Wildlife Habitat and Movement Patterns	4
Wildlife-vehicle Collisions Prior to the At-grade Crosswalk	5
<b>At-grade Crosswalk Mitigation Pilot Safety Project</b>	<b>6</b>
Wildlife-vehicle Collisions Following Construction of the At-grade Crosswalk	7
Wildlife Monitoring	14
<b>Factors Limiting the Effectiveness of the At-grade Crosswalk System</b>	<b>18</b>
<b>Long-term Mitigation Alternatives</b>	<b>19</b>
Crossing Structures for Elk: Overpasses and Underpasses	20
Stakeholder Collaboration & Public Input	23
Complementary Management Actions to Reduce Wildlife Conflict	27
Costs of Wildlife-vehicle Collisions	28
<b>Conclusions</b>	<b>29</b>
<b>References</b>	<b>31</b>

## Appendices

<a href="#">Appendix A</a>	Acronyms
<a href="#">Appendix B</a>	US Highway 6 Wildlife Crosswalk Monitoring Results
<a href="#">Appendix C</a>	US Highway 6 Wildlife Crossing Design Plans

## List of Tables

Table 1. Summary of elk use of wildlife crossing structure _____	20
Table 2. Economic cost of reported WVC accidents _____	29

## List of Figures

Figure 1. Elk on the Fossil Trace Golf Course _____	1
Figure 2. Elk resident population area and winter concentration habitat _____	4
Figure 3. At-grade crosswalk system on US 6 _____	6
Figure 4. Elk-vehicle collisions by milepost _____	8
Figure 5. Deer-vehicle collisions by milepost _____	9
Figure 6. Wildlife-vehicle collisions by year _____	11
Figure 7. Winter snowfall and average winter temperatures _____	12
Figure 8. Winter snowfall and reported WVC crashes _____	13
Figure 9. Number of individual elk successfully using the at-grade crosswalk _____	15
Figure 10. Number of successful elk crossing events _____	15
Figure 11. Number of failed elk crossing events _____	16
Figure 12. Annual comparison of successful crossing events, failed crossing events, and the total number of individual elk _____	17
Figure 13. Alignment of the separated wildlife underpass, Kinney Run Creek, and the box culvert for the bike/pedestrian trail _____	26



## Introduction

Linear transportation infrastructure, such as roads and highways, can affect wildlife populations in a variety of ways including habitat loss, habitat fragmentation, hindering animal movement, and mortality (van der Ree et al. 2015). Vehicle collisions with wildlife have become a major safety concern for motorists and transportation agencies, and the loss of individual animals can impact the health of local wildlife populations.

Elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) are abundant around the City of Golden and surrounding foothills and pose a threat to motorist safety on U.S. Highway 6 (US 6), which runs along the west side of the city at the base of the foothills. In particular, elk movements across US 6 between 19<sup>th</sup> Street and Heritage Road (milepost [MP] 272.6 – 273.9) increased markedly following the construction of the Fossil Trace Golf Course in 2002 on the site of a former clay mine on the east side of the highway. For many years, large signs warning motorists to watch for wildlife were in place along this stretch. Yet, despite this signage, 138 wildlife-vehicle collision (WVC) accidents were reported to law enforcement from 2003 through 2010, equating to a rate of 14.5 WVC per year for this 1.4-mile long segment.



**Figure 1. Elk on the Fossil Trace Golf Course.**

**Photo credit: Fossil Trace Golf Course**

Due to this high frequency of WVC, the Colorado Department of Transportation (CDOT) investigated various strategies for reducing WVC and improving safety along this stretch of US 6. At the time, funding was not available to construct a wildlife underpass or overpass. Instead,

in late 2010/early 2011, CDOT installed a less costly and somewhat experimental at-grade wildlife crosswalk to address these issues.

Immediately following the installation of the at-grade wildlife crosswalk and wildlife exclusion fencing there was a significant decrease in WVC as animals first encountered the new mitigation features. However, as wildlife learned the location of the at-grade crosswalk, WVC increased again to nearly pre-mitigation levels in subsequent years. Yet, WVC continue to be the second leading crash type on this segment of US 6, following rear-end accidents. Prior to the at-grade crosswalk, WVC accounted for 23% of all crashes from 2003-2010. Since the installation of the crosswalk in early 2011, WVC have accounted for 18% of all crashes. Most of these collisions resulted in property damage only, although 17 (8%) have also resulted in human injuries. The majority of WVC have been with elk (57%) or deer (38%), and the remainder involved other wildlife such as mountain lion and fox. No elk-vehicle collisions were recorded prior to the construction of the Fossil Course Golf Course in 2002, although species was not reported on accident reports involving wildlife prior to 2000. Following the golf course construction, elk-vehicle collisions averaged 9.8 per year from 2003-2010.

While elk-vehicle collisions are of particular concern in this segment, WVC with deer and other species also contribute to the WVC rate. Overall, an average of 14.5 WVC per year were reported for this segment between 2003 and 2010. After the installation of the at-grade crosswalk in early 2011, there was an initial sharp decrease in WVC as animals first encountered the wildlife fencing and learned the location of the at-grade crosswalk. Thereafter, WVC rates increased again to near pre-mitigation levels to an annual average of 11.8 WVC from 2012 through May 2017 when the construction of the US 6 / 19<sup>th</sup> Street grade-separated, unsignalized interchange was completed.

In the year and a half following the construction of the 19<sup>th</sup> Street interchange project (mid 2017 through 2018), WVC decreased to an average of 5.7 per year. However, in 2019, 12 deer and elk-vehicle collisions recorded were by the City of Golden (WVC crash data for 2019 from CDOT were not yet available at the time of this writing). In addition, during this timeframe

camera monitoring of the at-grade crosswalk detected a major shift in wildlife use of the at-grade crosswalk – a likely result of more constant traffic flows on US 6. Elk were bunching up at the crosswalk and the time for the herd to cross increased, causing potential stress to the animals. Riginos et al. (2018) determined that mule deer require a minimum of a 60 second gap between vehicles to perform a safe crossing – a condition that is rarely achieved except during the late-night hours on US 6. In 2019, the average traffic volume for this segment was 37,000 vehicles per day, which equates, on average, to a vehicle every two seconds; however, this does not account for variations in traffic flows throughout the day and night or on weekdays versus weekends and holidays when traffic gaps may vary. It is likely that elk have a similar, if not more stringent, requirement for gaps in traffic in order to accomplish a successful crossing.

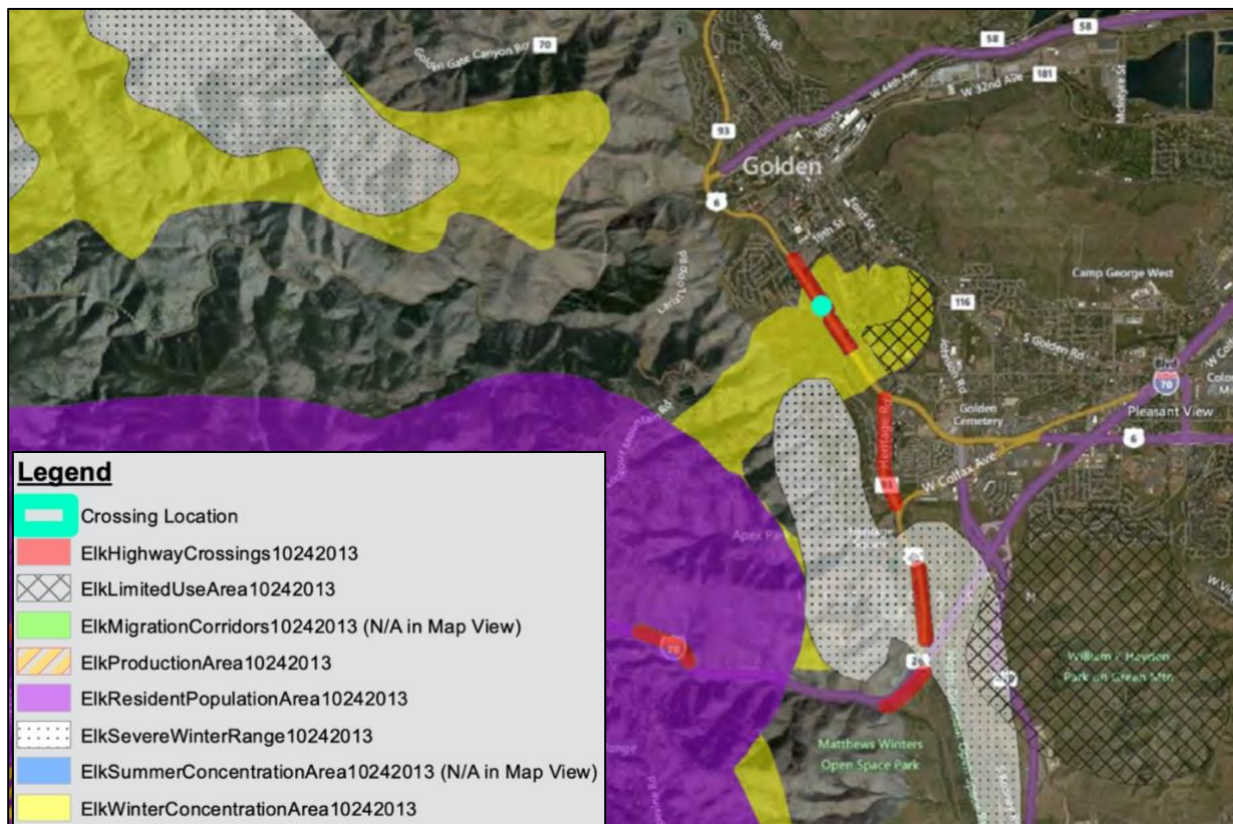
Once across US 6, the herd appeared to be spending longer stretches of two weeks or more on the golf course in Winter 2018/2019 before returning to the west side of US 6 (J. Segal, City of Golden, *pers. comm.*), although camera monitoring continued to detect subgroups crossing back and forth on a daily basis. In general, this behavior was in contrast to the daily crossings the entire herd was making before the construction of the 19<sup>th</sup> Street interchange. While the construction of the 19<sup>th</sup> Street interchange has likely affected wildlife activity at the at-grade crosswalk as described above, annual variations in movement patterns may have been influenced by a number of variables, including winter severity and adjustments to the mitigation system made by CDOT in 2016 and 2017.

## **Site Description**

US 6 is currently two lanes in each direction with a posted speed limit of 55mph. The traffic volumes on US 6 are currently 37,000 vehicles per day, which equates to an average of 1,542 vehicles per hour and 26 vehicles per minute. Traffic volumes are anticipated to increase to 41,662 vehicles per day by 2040. Colorado School of Mines owns the majority of open undeveloped parcels on the west side of US 6 between 19th Street and Heritage Road. The City of Golden has preserved open space in the vicinity of the Kinney Run drainage, south of the at-grade wildlife crosswalk.

## Wildlife Habitat and Movement Patterns

US 6 bisects habitat located at the base of the foothills in Jefferson County (City of Golden). Elk and mule deer typically move from higher elevation areas located on the west side of US 6 to access undeveloped, lower elevation habitat that supports vegetative and woody forage. Habitat on the west and east side of US 6 has been mapped as winter concentration areas for elk (Fig. 2). The Fossil Trace Golf Course is a major attractant to the resident elk during the fall and winter months, particularly when there is snow in the foothills. While elk appear to be primarily motivated by access to forage on and around the golf course, deer are known to move farther east to the open spaces on North and South Table Mountains. In addition to ungulate species, bobcat (*Lynx rufus*), mountain lion (*Puma concolor*), black bear (*Ursus americanus*), and a variety of small mammals are known to cross US 6 in this area, either via the existing culverts or via the at-grade crosswalk.



**Figure 2. Elk resident population area and winter concentration habitat, Colorado Parks and Wildlife. Map created by Tim DeMasters, 2015. Data source: CPW, 2013**

## **Wildlife-vehicle Collisions Prior to the At-grade Crosswalk**

Prior to the installation of the at-grade crosswalk, WVC were the second leading crash type (after rear ends) in the segment of US 6 between 19<sup>th</sup> Street and Heritage Road, accounting for 21% of all crashes from 2003 through 2010. Most accidents resulted in property damage only (92%), while 8% resulted in human injuries and none resulted in fatalities. WVC accidents occurred year-round, with those involving elk occurring primarily during the fall months. Few elk-vehicle collisions occurred during the summer when the elk herd is in the higher elevation foothills. Overall, the majority of WVC accidents were with elk (67%) or deer (31%), which reflects the predominance of the elk population in this landscape and their motivation to cross US 6.

Prior to the construction of the golf course in summer 2002, no elk-vehicle collisions were reported between 1997-2001, although species was not always recorded on accident reports prior to 2000. Following the golf course construction, elk-vehicle collisions averaged 9.8 per year from 2003-2010. Notably, elk-vehicle collisions on US 6 are uncommon outside of this 1.4-mile long segment, north of 19<sup>th</sup> Street or south of Heritage Road, indicating that elk movements across US 6 are motivated by the availability of winter forage around the golf course.

In contrast, deer are known to cross a broader segment of US 6 and move farther east to the open spaces on North and South Table Mountains. Deer-vehicle collisions have also been recorded north of 19<sup>th</sup> Street both prior to and following the construction of the golf course. Between 19<sup>th</sup> Street and Heritage Road, deer-vehicle collisions averaged 4.5 reported accidents per year prior to the installation of the at-grade crosswalk system (2003-2010) and continued to occur at about the same rate (4.7 deer-vehicle collisions per year) following the mitigation (2012-2018).

Wildlife-vehicle collision accidents are widely recognized as being underreported to law enforcement when an accident results in little or no damage to the vehicle and its occupant, or for other reasons. While WVC carcass pickups are reported by CDOT maintenance personnel on a voluntary basis, carcass reporting in this segment have been inconsistent and these data are not presented here. WVC carcass reporting has been very low in this segment for a number of reasons that do not reflect actual WVC conflict.

## At-grade Crosswalk Mitigation Pilot Safety Project

In late 2010, in an effort to improve motorist safety and reduce the frequency of WVC, CDOT installed an at-grade wildlife crosswalk on US 6 to improve roadway safety and reduce WVC.

The at-grade crosswalk, or crosswalk, consists of three components (Fig. 3):

- 8-foot high standard wildlife exclusion fence on either side of US 6 between 19th Street and Heritage Road, with a gap at the designated at-grade crosswalk location (MP 273.05).
- An animal detection system (ADS) located at the fence gap, which, when activated, alerts motorists to the presence of wildlife in the crosswalk. The ADS consists of infrared sensors that detect when an animal enters the right-of-way; and flashing lights on yellow warning signs on the highway shoulders and median that are activated by the sensors.
- Roadway striping meant to mimic cattle guards and boulders/rocks through the shoulders and median to channelize wildlife within the designated crosswalk.
- Escape ramps along the fenced segment that provide a means for animals to escape the right-of-way in the event they become trapped inside the fenced area.
- Roadside reflectors and audible warning devices at each fence end to deter wildlife from entering into the fenced right-of-way.



**Figure 3. At-grade crosswalk system on US 6. Photo credit: CDOT**

In response to ongoing WVC at the at-grade crosswalk, CDOT has implemented several additional improvements:

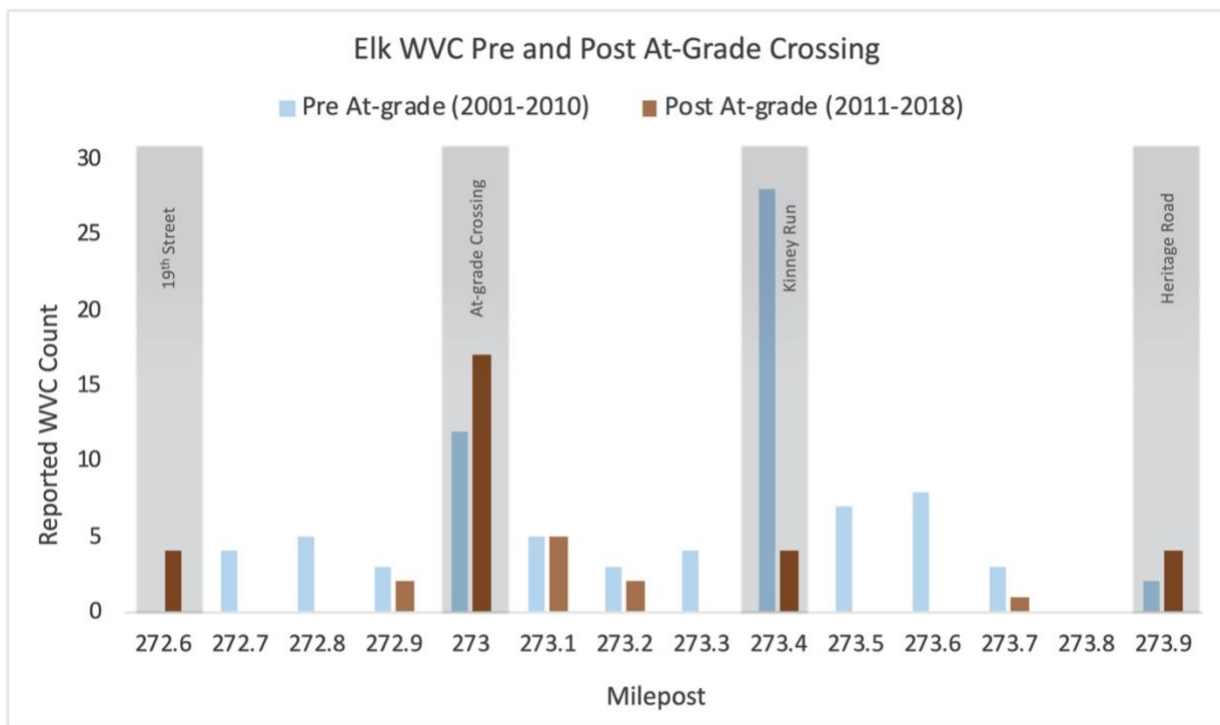
- Adjustments to the timing and duration of the flashing warning lights (January 2016);
- Wired LED lighting at the crosswalk to improve driver visibility of wildlife in the crosswalk during nighttime (November 2016);
- Temporary use of variable message signs during the fall months when elk activity is highest to provide additional driver warning in advance of the at-grade crosswalk (beginning in fall 2016);
- The addition of transverse rumble strips across the traffic lanes in advance of the at-grade crosswalk to alert approaching drivers of the crossing system and the potential need to stop in the event that animals are present in the crosswalk (2017);
- The construction of an additional escape ramp at the west end of the fenced segment, near Heritage Road (2017).

A lower rate of WVC in 2016-2018 suggest that these adjustments may have had a positive effect on decreasing WVC. However, the influence of these adjustments on the WVC rate is difficult to distinguish from other influences such as a succession of mild winters, which may have resulted in fewer elk attempting to cross US 6; and, since mid-2017, the completion of the 19<sup>th</sup> Street interchange project, which resulted in fewer gaps in traffic and subsequent changes in elk movement patterns as described above.

### **Wildlife-vehicle Collisions Following Construction of the At-grade Crosswalk**

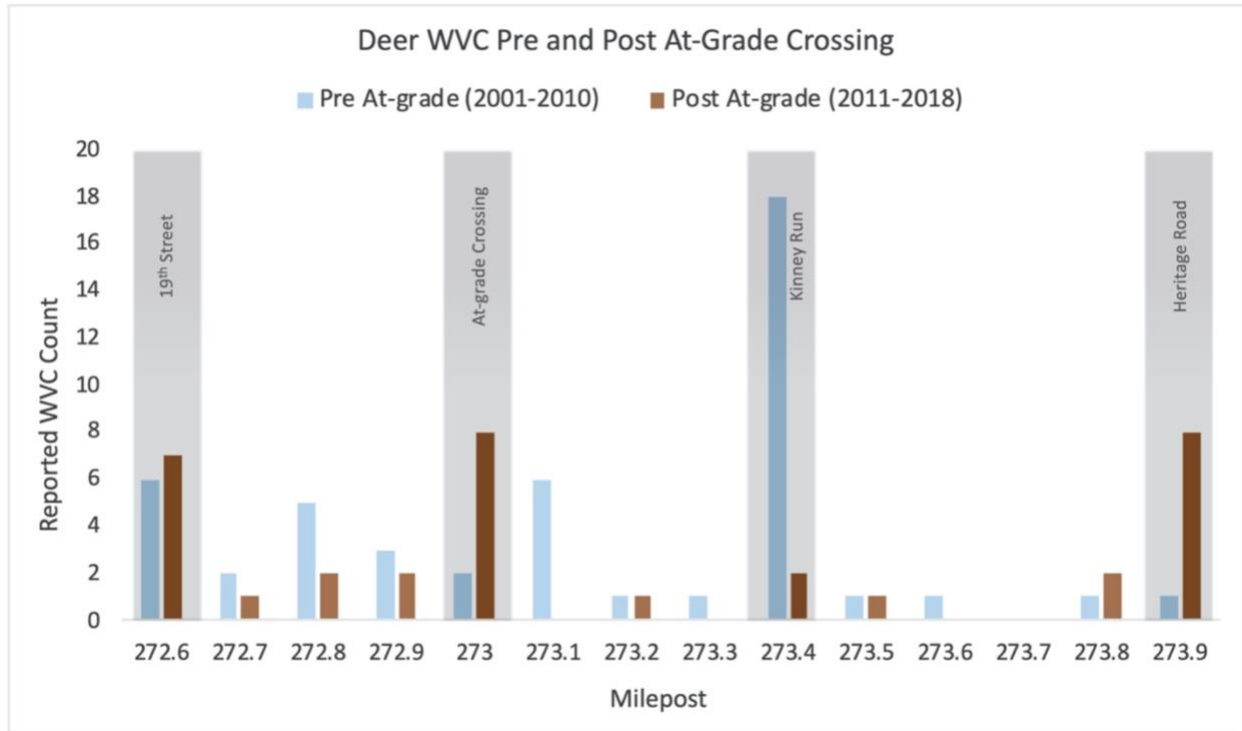
In addition to the shifts in WVC following the construction of the golf course, there have been two additional events that have led to both spatial and temporal changes in WVC patterns along this segment of US 6, 1) the installation of the at-grade crosswalk in late 2010/early 2011, and 2) the construction of the 19<sup>th</sup> Street interchange, which was completed in mid-2017.

Between 19<sup>th</sup> Street and Heritage Road, both deer and elk WVC were reported throughout the segment prior to the installation of the at-grade crosswalk. For both species, the majority of WVC occurred at Kinney Run (MP 273.4) during this timeframe. Kinney Run is a natural drainage corridor that provided direct access between undeveloped areas on either side of US 6. Following the construction of the at-grade crosswalk system, however, spatial patterns in crossing activity shifted. The new wildlife exclusion fencing prevented animals from crossing at Kinney Run and, as animals learned to navigate the at-grade crosswalk and associated fencing, wildlife movements across US 6 shifted primarily to the area around the designated crosswalk and to the fence ends at 19<sup>th</sup> Street and Heritage Road, as is reflected in the WVC accident data (Figs. 4 & 5).



**Figure 4. Elk-vehicle collisions by milepost 10 years prior to the installation of the at-grade crosswalk system (2001 – 2010) and 8 years following the installation of the at-grade crosswalk system (2011-2018).**





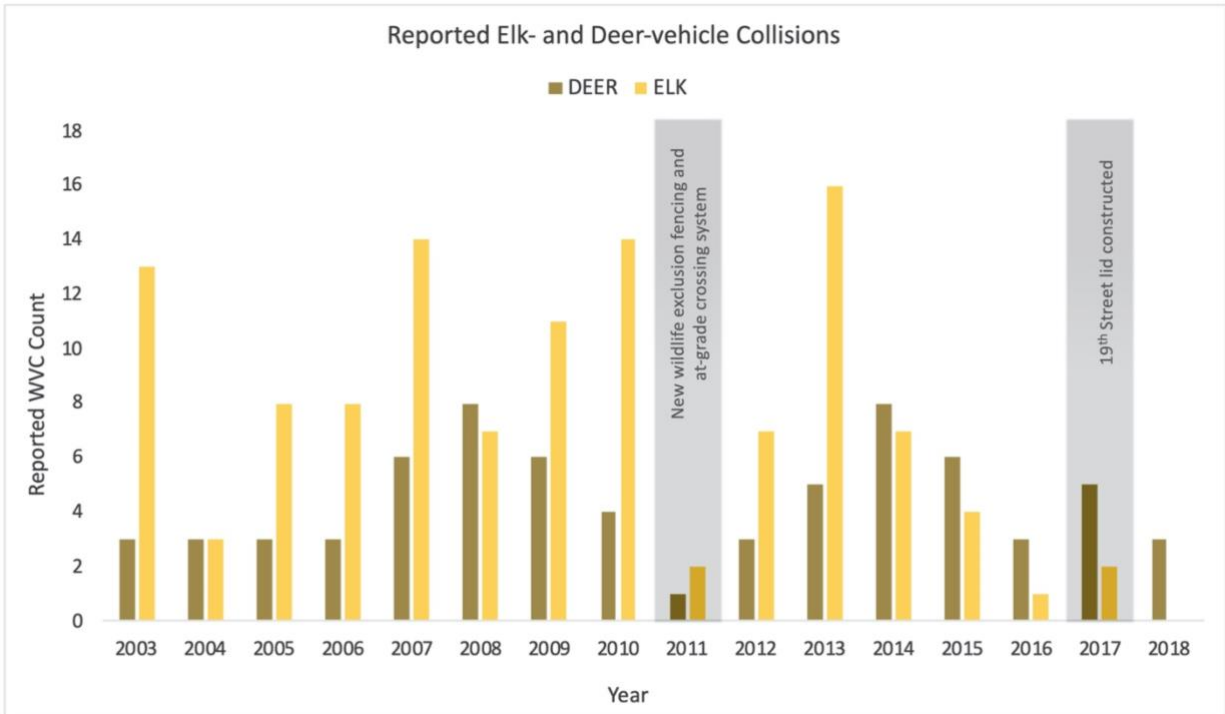
**Figure 5. Deer-vehicle collisions by milepost 10 years prior to the installation of the at-grade crosswalk system (2001 – 2010) and 8 years following (2011-2018).**

Despite the presence of the detection system warning drivers of the potential for wildlife in the crosswalk, WVC have continued to occur mostly around the at-grade crosswalk, with some animals moving outside of the designated crosswalk and becoming trapped inside the fencing. Deer- and elk-vehicle collisions decreased throughout much of the remainder of the segment due to the presence of the fencing but collisions still occur at both fence ends – particularly at Heritage Road where animals are known to attempt crossing back over US 6 from east to west.

It is apparent from the sharp decrease in WVC in 2011 that animals were largely barred from crossing US 6 during the first year following construction of the wildlife exclusion fencing. Once animals learned the location of the gap in the fencing where the animal-detection system is located (MP 273), WVC increased again. Prior to the mitigation installation, elk-vehicle collisions averaged 9.8 reported accidents each year (2003-2010). Post-mitigation (excluding the dip in WVC in 2011), elk-vehicle collisions decreased to an average of 6.4 elk-vehicle collisions

each year from 2012 through May 2017, when the construction of the 19<sup>th</sup> Street interchange was completed. A similar pattern is evident when considering WVC with all species – prior to the at-grade crosswalk there were an annual average of 14.5 WVC, which decreased to an average of 11.8 WVC per year from 2012 through May 2017. At this level, the rate of WVC are still higher than the threshold of 5.1 WVC per mile per year at which wildlife crossing structures are considered cost-effective with net public benefits (Huijser et al. 2009).

Further shifts in wildlife movement patterns appear to be occurring since the completion of the 19<sup>th</sup> Street interchange in mid-2017 (Fig. 6). The removal of the signal has resulted in more constant traffic flows on US 6 (i.e., fewer gaps during which animals may cross) and higher speeds. These changes in traffic patterns appear to be increasing the barrier effect of traffic on wildlife movement at the at-grade crosswalk. While only preliminary data are available, from June 2017 through 2018, WVC decreased to an average of 5.7 WVC per year. An increase in the barrier effect is corroborated by camera monitoring at the at-grade crosswalk, which has documented a longer crossing time for the elk herd at the at-grade crosswalk and an increase in repel behavior before an animal attempts crossing at the crosswalk (see below section on Wildlife Monitoring). In Winters 2017-18 and 2018-19, the herd was observed by Golf Course personnel to be spending longer stretches of two weeks or more on the golf course before returning west. In Winter 2019-20, however, camera monitoring detected a sharp increase in the number of crossing events with fewer elk per crossing event. Correspondingly, WVC also appear to have increased in 2019, with 12 deer and elk-vehicle collisions recorded by the City of Golden.

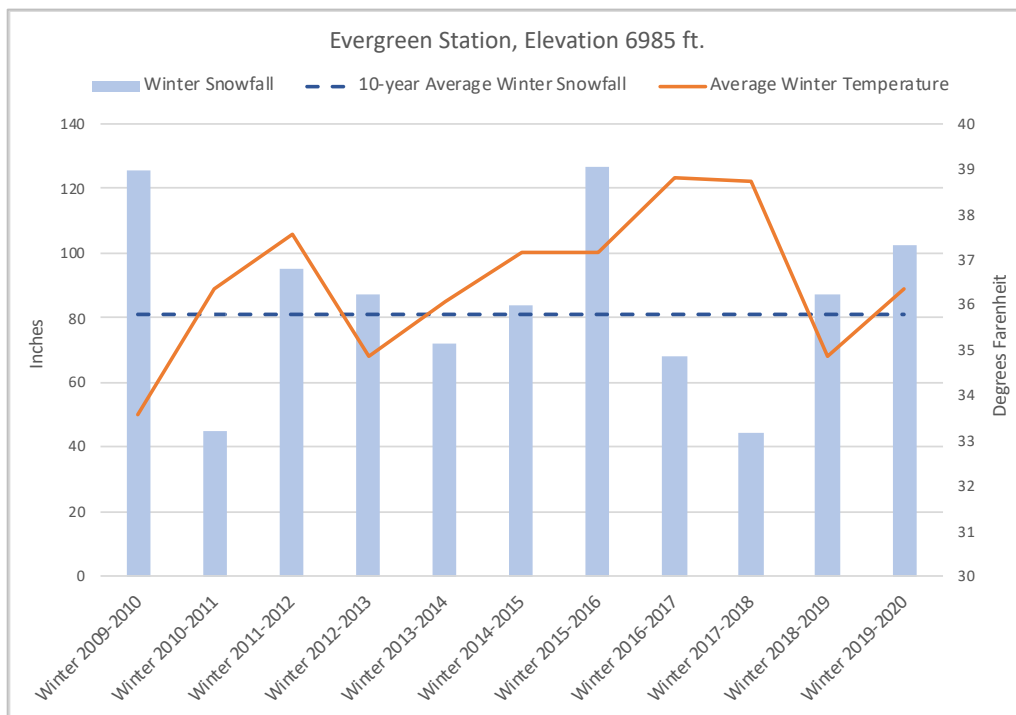


**Figure 6. Wildlife-vehicle collisions by year (MP 272.6-273.9). Fossil Trace Golf Course was constructed on the site of a former clay mine in 2002, attracting elk across US 6. In late 2010/early 2011 the at-grade crosswalk and wildlife exclusion fence were installed. Construction of the 19th Street interchange was completed in mid-2017.**

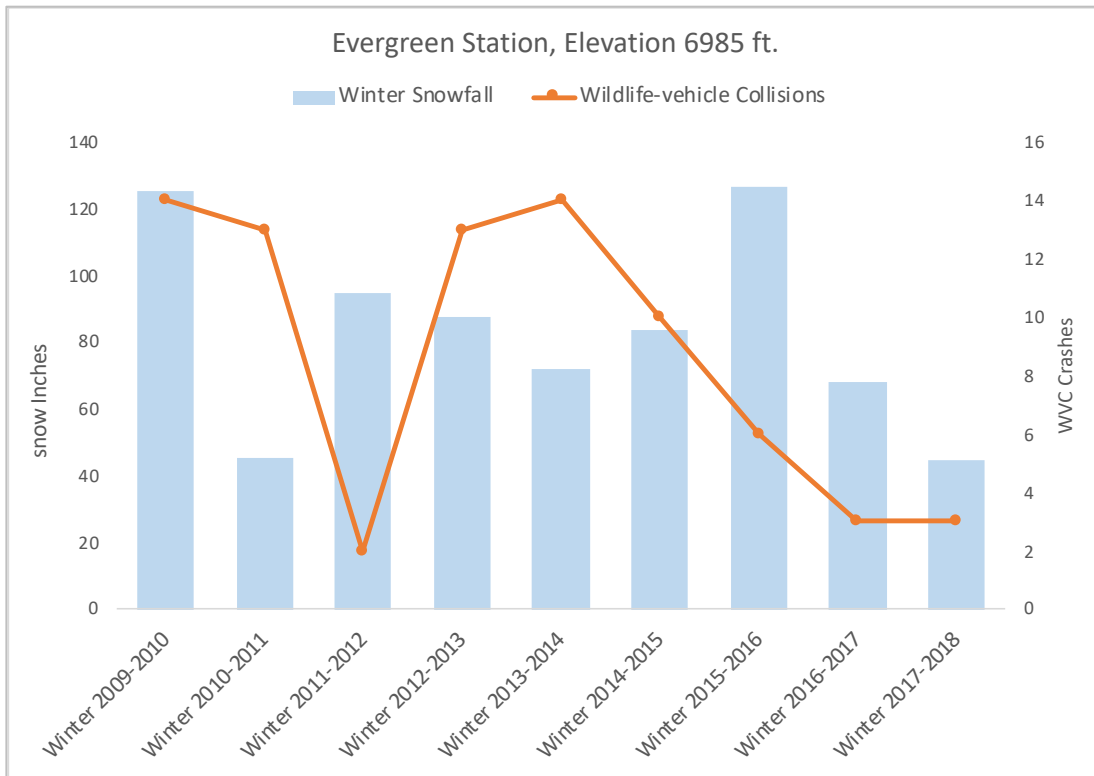
Elk do not appear to be attempting to cross US 6 via the 19<sup>th</sup> Street interchange. Wildlife exclusion fencing extends from south from Heritage Road to 19<sup>th</sup> Street but no fencing is present north of the interchange, and there are no mitigation features (e.g., wildlife guards) preventing wildlife access onto the interchange. It is likely that fox (*Vulpes vulpes*), coyote (*Canis latrans*) and adaptable smaller fauna such as raccoon (*Procyon lotor*) may use the interchange to pass over US 6. Deer may also make occasional crossings. It is anticipated that elk are less likely to use the 19<sup>th</sup> Street interchange as a crossing location due to adjacent development; vehicle, bicycle and pedestrian traffic and other human activity, particularly during daylight hours; and a lack of suitable habitat – much of the land immediately surrounding the interchange is occupied by buildings and pavement, particularly on the east side. In addition, elk generally only move as far north as the at-grade crossing and, having found the gap in the fence, have no need to move

farther north towards the interchange. It will be important to continue to evaluate wildlife use of the interchange and, in particular, prevent elk from accessing the interchange and potentially entering onto US 6 via the on/off ramps.

Winter severity – including snowfall, snow depth and temperature – in the foothills above Golden are expected to have some impact on elk and deer movement across US 6 and, subsequently, on WVC (Fig. 7). However, given that there are multiple interacting variables influencing wildlife movements, it is difficult to distinguish any direct correlations between winter conditions and WVC rates (Fig 8).



**Figure 7. Winter snowfall and average winter (October-May) temperatures from 2009-2020. The Evergreen weather station was used as data for the Golden weather station on Lookout Mountain were incomplete. Annual patterns in snowfall and temperature are similar at both weather stations, although the Evergreen weather station records greater annual snowfall than the Golden Station.**



**Figure 8. Winter snowfall and reported WVC crashes, Winter 2009-2010 through Winter 2017-2018. Winter snowfall months include October through May. WVC data are incomplete for 2019.**

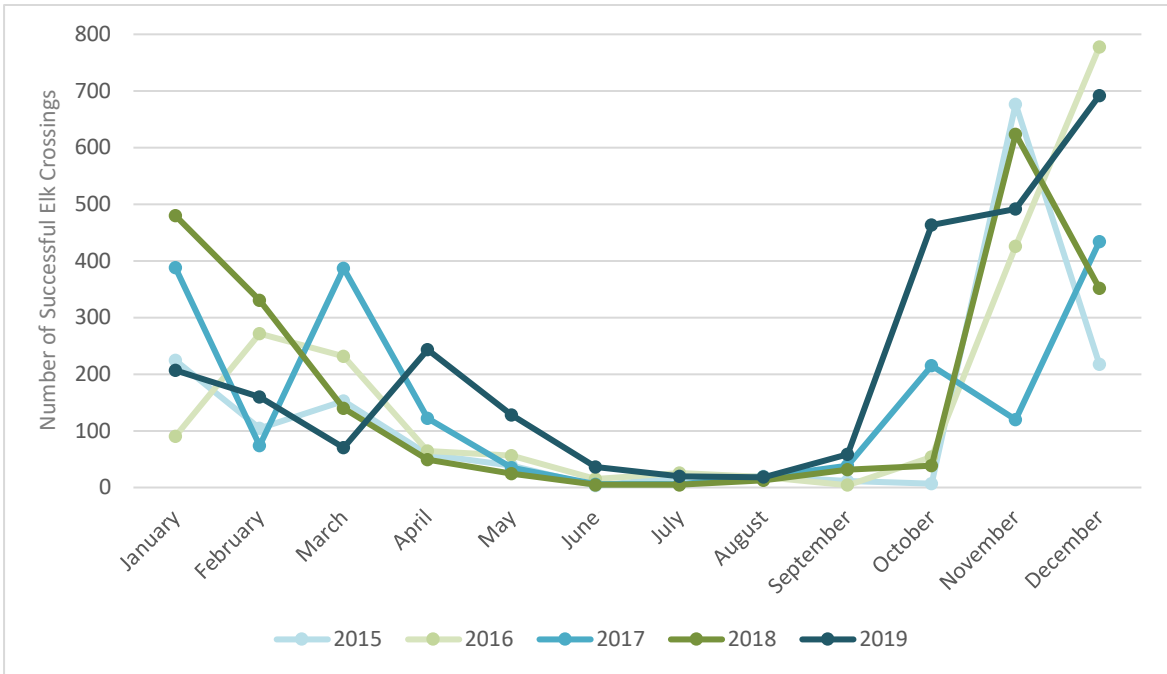
The at-grade crosswalk has also affected the diurnal patterns of WVC. Prior to the at-grade crosswalk, most WVC occurred at night (86%). Just 10% of occurred at dawn or dusk, which is when animals in a wild setting are typically most active. However, in this suburban setting, dawn and dusk correspond with the highest daily traffic volumes as commuters drive to and from work (particularly in the winter months), and it is presumed that the elk adapted their movement patterns to correspond with lower nighttime traffic volumes. Such temporal shifts in elk movements in response to traffic volumes have been documented elsewhere (e.g., Gagnon et al. 2007). Following the installation of the mitigation system, however, the proportion of WVC occurring during the nighttime hours decreased (to 57%) while the proportion of WVC occurring at dawn and dusk increased (to 33%). The warning system is active both day and night; therefore, it is speculated that the roadway lights at the at-grade crosswalk may be useful in

providing drivers with better visibility to detect wildlife presence at the crosswalk, regardless of the reliability of the detection system.

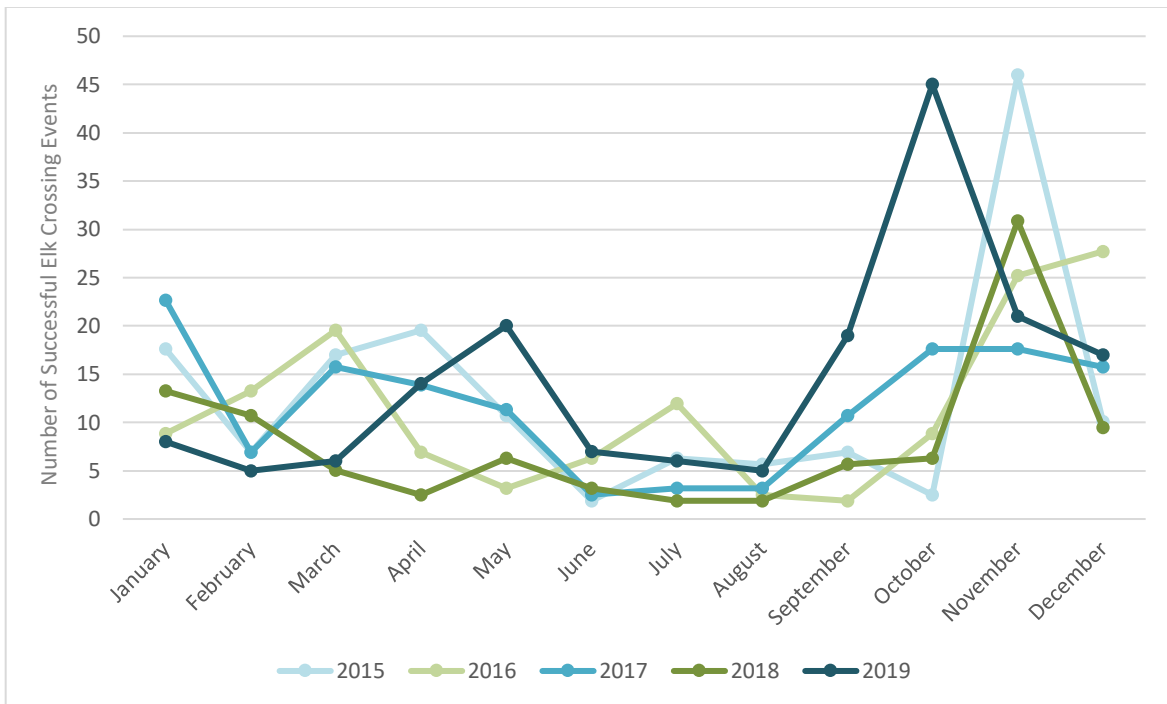
### **Wildlife Monitoring**

In October 2014 CDOT began a wildlife camera monitoring study of the US 6 at-grade wildlife crosswalk to document wildlife use patterns (species, frequency, and timing of use). CDOT installed wildlife monitoring cameras on each corner of the at-grade wildlife crossing. Information such as date, time, species, the number of animals, direction of crossing, and crossing success/failure is logged and recorded for each crossing event (Appendix B).

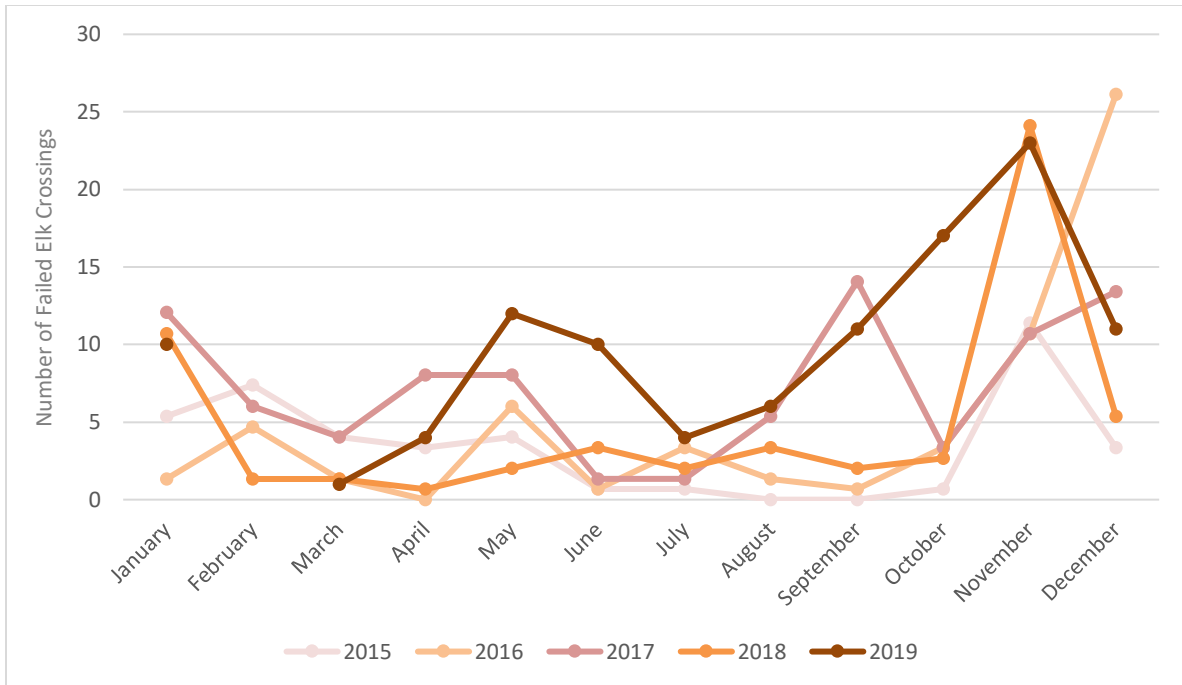
From October 2014 through December 2019, 11,330 individual successful westbound elk movements were documented at the at-grade crosswalk (Fig. 9) in 780 successful crossing events (Fig. 10). This equates to a crossing success rate of approximately 77% for individual elk movements. A crossing event is composed of an individual or a group of elk using the at-grade crosswalk at the same time. A single crossing event may last a few seconds or up to a few hours, depending on the size of the group and whether all individuals were able to cross together, or some were initially deterred from crossing due to approaching traffic. In addition to successful crossings, some wildlife approaches to the at-grade crossing resulted in failed movements where the animal repelled from the at-grade crossing, typically due to traffic. An additional 3,385 individual failed elk movements were documented during this timeframe in 389 failed crossing events (Fig. 11). This equates to a crossing failure rate of 23% for individual elk movements.



**Figure 9. Number of individual elk successfully using the at-grade crosswalk, 2015-2019. Note y-axis scale is 0-800.**



**Figure 10. Number of successful elk crossing events (single elk or herd of elk crossing at the same time), 2015-2019. Note, y-axis scale is 0-50.**



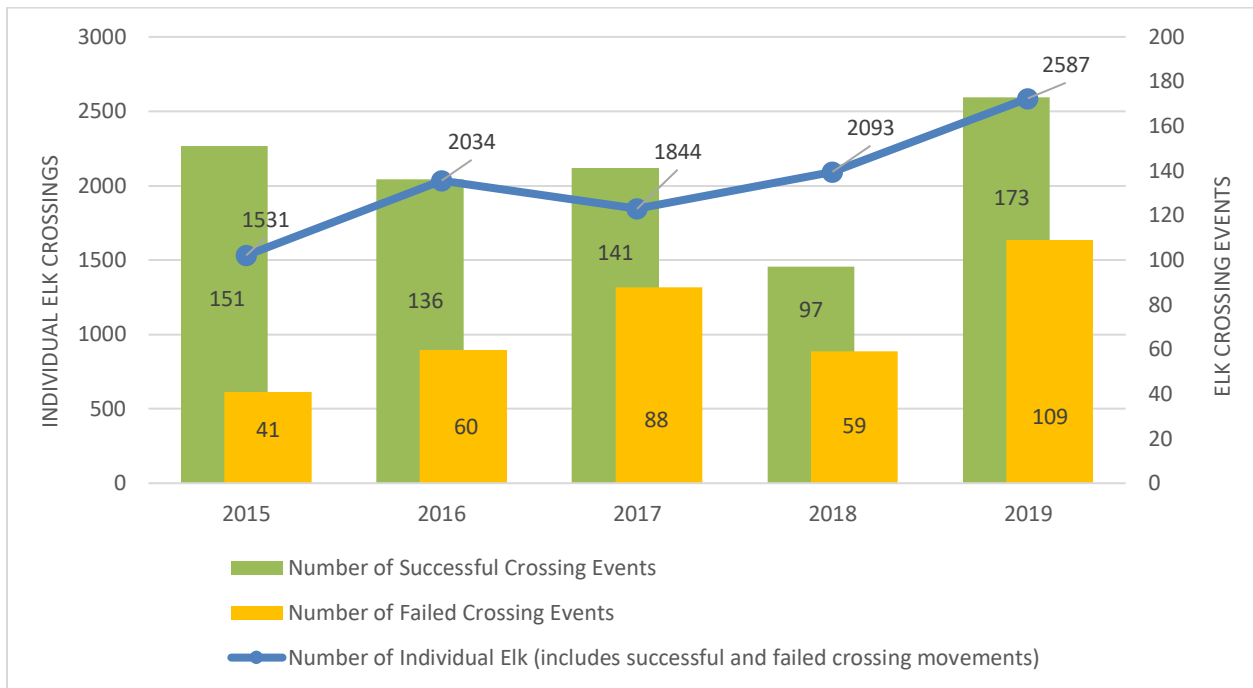
**Figure 11. Number of failed elk crossing events (single elk or herd of elk crossing at the same time), 2015-2019. Note, y-axis scale is 0-30.**

Successful elk crossings, successful elk crossing events, and failed elk crossing events were highest in the late fall across all years, generally October-December with a peak, in most cases, in November. The total number of successful movements decreased in April and May and remained low through the summer months (June to September). These movements were made primarily by individuals, pairs or small sub-herds. Conversely, during the fall, winter and early spring months, most movements were made by animals traveling in herds averaging between 10-30 animals with the maximum herd sizes ranging from 73-130 animals.

Overall, while the number of individual successful elk crossings has increased from 2015-2019, the number of successful and failed elk crossing events has varied from year to year (Fig. 12). Both successful crossing events and failed crossing events decreased in 2018, corresponding with the timeframe following the completion of the 19<sup>th</sup> Street interchange and subsequent changes in traffic patterns. Yet, despite this decrease in the total number of crossing events, in 2018, the number of individual elk movements – including both successful crossings and failed



attempts – continued to increase, indicating an increase in the number of elk per crossing event. In 2019, successful crossing events, failed crossing events, and the total number of elk movements were all at their highest in the five-year monitoring timeframe. The number of elk per crossing event decreased again to a level consistent with the years prior to the interchange construction (2015-2017). The crossing success rate of elk that approached the crosswalk was highest in 2015 (79%) and decreased in 2016 (70%) and 2017 (62%), where it remained consistent through 2018 and 2019.



**Figure 12. Annual comparison of successful crossing events, failed crossing events, and the total number of individual elk, including both successful and failed crossing movements, 2015-2019.**

In addition to elk, a variety of wildlife has been documented using the at-grade wildlife crosswalk including, mule deer, bobcat, coyote, raccoon, and eastern cottontail (*Sylvilagus floridanus*).

## Factors Limiting the Effectiveness of the At-grade Crosswalk System

The functionality of the at-grade crosswalk depends on 1) the accuracy of the infrared sensor in detecting wildlife with minimal false positives, and 2) drivers responding to the warning lights appropriately by slowing down and stopping before the crosswalk. Both of these components have remained unreliable since the installation of the at-grade crosswalk system. There are several contributing factors affecting system effectiveness:

- The at-grade crosswalk system was modeled after a wildlife crosswalk on State Route (SR) 260 in Arizona. Researchers for the SR 260 crosswalk concluded that wildlife crosswalks are recommended for two-lane roads with low to moderate traffic volumes (< 8,700 AADT) and posted speed limits of 55 mph or lower (Gagnon et al. 2010). In comparison, this segment of US 6 has 4 traffic lanes, a speed limit of 55 mph, and in 2011, traffic volumes were 43,000 AADT and have since increased to 48,000 AADT in 2019.
- Rather than the painted white lines used on US 6, the SR 260 at-grade crosswalk uses electrified mats across the roadway to prevent wildlife movement outside of the crosswalk. Cramer 2014 notes that painted white lines intended to mimic cattle guards are almost completely ineffective at preventing mule deer, elk and moose from crossing. Incidence of WVC beyond the at-grade crosswalk indicate that the painted lines intended to mimic cattle guards on US 6 are not effective in containing wildlife inside the designated crosswalk.
- Most studies evaluating the effectiveness of reflectors and auditory deterrents such as those used at the fence ends on US 6 have determined that these types of deterrents have either no effect or an indeterminate effect on WVC rates (Hedlund et al. 2003). In some cases, an initial effect on wildlife was documented but not sustained over the long-term as animals became habituated (Ujvari et al. 1998). Ujvari et al. 2004 found that deer became completely indifferent to acoustic stimuli within ten days. Roadside reflectors are also impossible to keep clean at all time, particularly during winter months (Huijser et al. 2008), further limiting any potential influence on WVC.

- The ADS was never fine-tuned to ensure that both false positives (warning lights flashing when no animal is present) and false negatives (no warning lights when an animal is present) were minimized to the greatest extent possible. Such system reliability is essential so that drivers learn to trust the system and respond accordingly. Over the years, local drivers have regularly commented on community forums that the warning lights are not working properly (either flashing all the time or, in some cases, not flashing when wildlife is present). In part due to this system unreliability, drivers commonly maintain their speed through the crosswalk even when the lights are flashing. In many cases, no wildlife is present, and the drivers may proceed ahead safely. However, drivers do not necessarily slow down when wildlife is present and, in some cases have been known to honk and drive through the herd as it is attempting to cross the highway. Driver compliance is an important factor in this type of mitigation system and, while no attempts have been made to measure driver compliance, it is commonly known to be partial, at best and, in some cases has resulted in WVC.
- Driver education is an important component of a wildlife crosswalk system as its success depends on driver awareness and their willingness to slow down and stop in response to the warning lights. However, outside of an initial press release when the at-grade crosswalk was installed, little effort was put into driver education and, consequently, drivers have remained somewhat ignorant of the crosswalk system. In 2015, the City of Golden created a flyer regarding the at-grade crosswalk system that was distributed to residents and CDOT has, over the last few years, placed a portable, changeable message sign in the segment alerting drivers during the peak fall elk crossing season.

## **Long-term Mitigation Alternatives**

This report concludes that the at-grade wildlife crosswalk is not fulfilling the objectives of improving roadway safety, reducing WVC, and providing safe passage for wildlife across US 6. Further, as traffic volumes increase and traffic speeds remain consistently higher with the elimination of the signals at 19<sup>th</sup> Street and, in the future, at Heritage Road, it is anticipated that

both WVC and the barrier effect of the road will increase over time. To this end, CDOT has determined that structural mitigation – specifically, a wildlife crossing structure with wildlife exclusion fencing – is warranted along this segment of US 6. While investments in wildlife crossing structures are typically made in wild or rural settings, mitigating wildlife-transportation conflict is also important in more suburban settings. Several studies have documented crossing structure effectiveness in mixed suburban-wildland landscapes and recommend wildlife crossing mitigation in these situations (Cramer and Hamlin 2017; Nielsen et al. 2003).

### **Crossing Structures for Elk: Overpasses and Underpasses**

In 2015, CDOT began considering replacing the at-grade crosswalk with a wildlife crossing structure. Wildlife crossing structures with wildlife exclusion fencing are widely recognized as the most effective strategy for providing wildlife habitat connectivity across roads and reducing WVC (Clevenger and Huijser 2011). The project team reviewed the dimensions and effectiveness of overpass and underpass structures for elk at locations across the western United States to inform the major design components for a wildlife crossing structure on US 6. These findings are presented by location in Table 1.

**Table 1. Summary of elk use of wildlife crossing structures across the western United States and Canada.**

<b>Location</b>	<b>Structure Type &amp; Dimensions</b>	<b>Conclusions</b>	<b>Source</b>
Arizona: SR 260 (4-lane, divided)	Two divided bridges, one with vertical walls, one with 2:1 sloped walls. Each bridge is 135’ span by 22’ high by 175’ long. Slope wall structure is 32’ wide at the floor.	Preference for bridge with natural, 2:1 slopes over vertical walls; however over time elk habituated to structure with vertical walls. Sloped wall structure had 75% success rate for elk with thousands of passages (2002-2006)	Dodd et al. 2007

**Table 1 (continued)**

Location	Structure Type & Dimensions	Conclusions	Source
Canada: Trans-Canada Highway, Banff	Bridges measuring 32-33' span by 9-10' high by 89' long, including median.	Bridge structures had highest elk usage rates (over culverts). Elk passage positively correlated with width, height and openness; negatively correlated with length and noise.	Clevenger and Barrueto 2014
Colorado: SH 9	Arch underpasses (44' span by 14' high by 66' long); overpass (100' wide by 66' long)	In first 3 years of the study, 94% success rate for elk passage (n = 34) at overpasses. Underpass success rate = 88% (n = 42)	Kintsch et al. 2019
Montana: US 93 North	Large culverts (24-25' span by 17-18' height by 98-128' long); overpass (197' span by 207' long)	Elk use of overpass greater than underpass structures, but cows almost exclusively using underpasses.	Huijser et al. 2016
Montana: SH 200 (2-lane)	3-sided box culvert measuring 20' span by 12' high by 40' long.	1000+ elk passages in 2 years of monitoring, including use by small herds. Not measuring success/repel rates.	P. Strum, Montana Dept. Transp., personal communication (via Pat Basting)
Montana: I-90	Bridge underpass without wildlife exclusion fencing	100 elk passages documented; unknown success/repel rate.	Servheen et al. 2003
Utah: I-70 (4-lane, divided)	Consplan arches measuring 48' span by 16' high by 39' long with open, vegetated median.	Most successful crossing for elk in Utah, although habituation to the structures by cows with calves and larger herds was slow.	Cramer 2014
Utah: I-15	Bridge 70.5' wide by 13.5' high by 65.6' long with open median	Several dozen elk passages recorded.	Rosa 2006
Utah: I-15 (4-lane, divided)	Overpass comprised of a set of bridges over I-15 with each bridge measuring 22' wide and 196' long with a 111' wide vegetated median.	Second-most heavily used structure by elk in statewide study; however, use primarily by bull elk. Only one cow crossed successfully.	Cramer 2014

**Table 1 (continued)**

<b>Location</b>	<b>Structure Type &amp; Dimensions</b>	<b>Conclusions</b>	<b>Source</b>
Washington: I-90 (4 lane, divided)	Each bridge measures 150' span by 12' high by 30' long with an open, vegetated median.	Elk may use low span bridges provided that the width is at least 100' allowing good visibility and provides accessible escape routes.	Kintsch and Cramer 2011
Wyoming: US 30 (2 lane)	7 box culverts, each measuring 20' span by 10-11' high by 60' long.	Only known regular use of box culverts by elk; however, use appears incidental (<5 animals per occurrence).	Sawyer et al. 2012

Cramer et al. (2014) summarized crossing structure use by elk across Utah based on multiple research studies. The report concludes that large bridge underpass and overpass are the only structure types with documented regular use by large groups of elk. Box culverts were occasionally used by individual elk and groups of fewer than six but were avoided by larger groups. The report recommends that overpasses for elk be at least 50' wide to accommodate movements by larger groups including cows with calves, although width recommendations must be adjusted to accommodate the roadway footprint and other site-specific considerations.

Clevenger and Huijser (2011) generally recommend that underpasses for large mammals, including elk, be a minimum of 20-40' span, 10-15' high, and less than 230' long, noting that the longer the structure the wider and higher it should be. However, based on the findings in Table 3, this guideline may be considered a minimum recommendation. In particular, Cramer (2014) recommends that underpasses for elk not exceed 100' in length. Notably, even within a species, not all populations are alike, and even the differences from one individual to the next may affect behavioral responses to a crossing structure. For example, use of smaller than optimum structures may occur where either wildlife have become habituated to a crossing structure in their range or to humans and roads (Donaldson 2005) or where prey species have relaxed antipredator responses due to absence of predators (Caro 2005).

As elk are warier than deer, any crossing structure designed for elk passage must meet these minimum requirements, to the extent that these are understood. In the context of US 6, the elk population is a resident herd and is not hunted. The suburban nature of this landscape indicates that this herd is habituated to human activity. In addition, the herd is known to be highly motivated to access winter forage on the golf course and surrounding open space. These factors suggest that the herd might tolerate a wildlife crossing structure across US 6 that is less ideal than what a more remote, migratory herd might require. In addition, a study on US 93 in Montana determined that wildlife crossing structures in suburban-wildland settings can be very effective in promoting successful passage by a variety of wildlife (Cramer and Hamlin 2017).

### **Stakeholder Collaboration & Public Input**

From 2015-2018, CDOT held three meetings and a site visit with stakeholders and two public meetings. Participants included the City of Golden (Road and Bridge Department, Trails Department, Animal Control, Fossil Trace Golf Course), Golden Police Department, Jefferson County Open Space, and Colorado Parks and Wildlife (CPW). Several of these stakeholders continued to participate in CDOT meetings to develop the mitigation designs.

Since the onset of these meetings, Fossil Trace Golf Course has expressed its concerns about ongoing elk damage to the golf course, and CPW has more generally expressed concerns about elk management east of US 6 and the potential for elk movement to continue farther east into residential areas around the Rolling Hills and Applewood golf courses, which similarly serve to attract elk. Elk do not typically browse on the greens, but elk damage occurs when the animals walk across the greens and may result in damages of \$20,000 annually.

The group discussed multiple alternatives for mitigating WVC including:

**1. No action – Maintain the existing at-grade crosswalk system.**

Pros: No design/construction costs

Cons: Due to the grade-separated interchange at 19<sup>th</sup> Street and a similar future interchange improvement at Heritage Road and associated reductions in the gaps between

traffic this option was determined to be insufficient for addressing wildlife-vehicle conflict. Increasing traffic volumes alone will not suffice in preventing elk-vehicle collisions as long as the motivation to cross exists (e.g., Gagnon et al. 2007) and more consistently high traffic speeds due to the removal of the stoplights may increase the severity of accidents that do occur. In addition, the group was concerned that if the at-grade crosswalk becomes more difficult for wildlife to use, they may become increasingly motivated to try crossing at the 19<sup>th</sup> Street interchange and at Heritage Road.

**2. Fencing off the entire highway segment between 19<sup>th</sup> Street and Heritage Road.**

Pros: Low design/construction costs. This action is intended to discourage elk movement east of US 6.

Cons: The group recognized that as long as the Fossil Trace Golf Course exists, elk will continue to find a way to access the golf course. A variant on this alternative was to extend wildlife exclusion fencing behind Centura and the Heritage neighborhood; however, CDOT can only maintain fencing within its right-of-way. These options risk moving the WVC problem to another location that may become even more difficult to mitigate. Determined elk as well as residents desiring access to the adjacent open space are likely to create holes in the fence, a situation which can become more problematic than no fencing at all. In addition, while escape ramps are important mitigation feature allowing animals that are trapped inside fencing to find an escape route, escape ramps cannot control wildlife activity along an extended segment of wildlife fencing without a suitable crossing structure. Both of these options would lead to an overall decrease in elk access to already limited winter range.

**3. Habitat improvements on the west side of US 6 to encourage elk to remain on the west side of the highway.**

Pros: Low cost; does not involve infrastructure improvements.

Cons: CPW determined that such a management action is likely to draw more wildlife towards the highway.



**4. Hazing on the golf course to discourage elk.**

Pros: Low cost; does not involve infrastructure improvements; localized management action.

Cons: Previous attempts to haze elk have proved unsuccessful. This is consistent with research from other locations on the use of hazing to discourage wildlife activity.

**5. Replacing the at-grade crosswalk system with a wildlife crossing structure.**

Pros: This alternative would also provide an opportunity for improving the alignment of Kinney Run Creek and the recreation path under US 6 and is expected to have the greatest impact on reducing WVC.

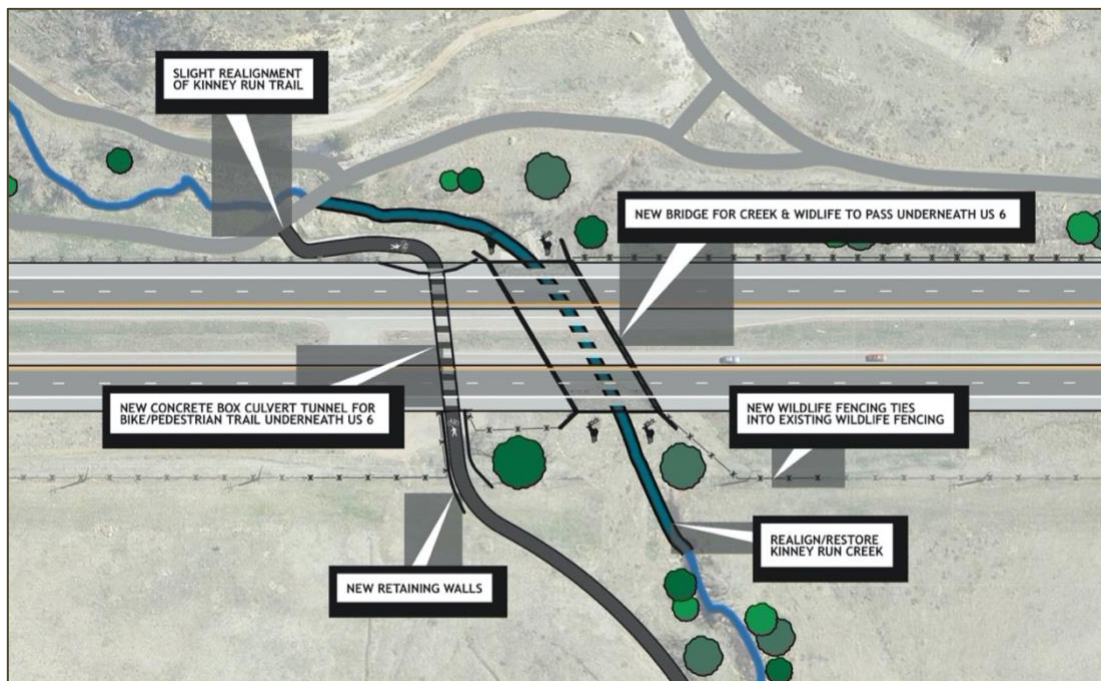
Cons: This alternative would continue to facilitate elk movement onto the Fossil Trace golf course and other areas on the east side of US 6. As a result, this alternative may lead to increases in wildlife conflict within the city.

Given this evaluation of the different alternatives, all the stakeholders agreed that human safety on US 6 is a paramount concern and that a wildlife crossing structure offered the best option for addressing the WVC issue. In 2016, the City of Golden in coordination with CDOT received \$500,000 in grant funding to initiate design and environmental review for a wildlife crossing structure to replace the at-grade crosswalk.

Subsequently, in April 2019, an open house was held to receive public input on 3 possible design alternatives for the wildlife crossing structure: 1) a bridge underpass over Kinney Run Creek with a separate box culvert for the recreation trail; 2) a shared use bridge underpass that would incorporate the creek crossing, wildlife movement, and the recreation trail; and 3) a wildlife overpass south of Kinney Run. Fourteen people made comments at the meeting, with additional comments made via the city's online project page. Participants at the open house generally favored a bridge underpass with a separate structure for the recreation trail as the best alternative for minimizing wildlife conflict both on the roadway and along the recreation trail, while online commenters generally preferred the overpass option.

The separated underpass option is favorable for multiple reasons, 1) Kinney Run was the primary crossing location for elk prior to the installation of the wildlife exclusion fencing and the at-grade crosswalk system, and it is expected that it will be less difficult for elk to re-adapt to using this natural crossing location; 2) the separated underpass option maximizes the benefits to both wildlife and human users and reduces the likelihood of conflict between these distinct uses; 3) a wildlife underpass is generally less expensive than an overpass.

Based on the project team’s evaluations and public input on each of these alternatives, CDOT has proceeded with the design for the preferred crossing structure alternative to replace the existing double box culvert at Kinney Run (Fig. 13). The design team completed its preliminary design phase (Field Inspection Review [FIR], equivalent to 30% design) in November 2019, and completed final design (Final Office Review [FOR], equivalent to 85-90% design) in Fall 2020 (see Appendix C for the wildlife crossing plans). While construction funding has not been identified, the project partners remain committed to enhancing safety for motorists and wildlife across US 6.



**Figure 13. Alignment of the separated wildlife underpass, Kinney Run Creek, and the box culvert for the bike/pedestrian trail (milepost 273.4). Drawing courtesy of HDR.**

Several wildlife-specific considerations must be reviewed as the project continues through the design and, eventually, construction phases:

- The closure of the at-grade crosswalk should be scheduled during the summer months when elk are not present in this area, following the construction of the bridge wildlife crossing at Kinney Run. As elk typically have a longer learning curve when adapting to a new crossing structure, temporary wildlife fencing along the west side of the neighborhood north of the at-grade crosswalk may be used to prevent elk from opting to use the 19<sup>th</sup> Street interchange. Limited baiting at the new wildlife crossing structure combined with strategic hazing at the 19<sup>th</sup> Street interchange may also be warranted during this transition time.
- Designs and complementary actions must prevent elk and other wildlife access onto the 19<sup>th</sup> Street interchange intersection.
- Designs should include improvements to the southern fence terminus to inhibit wildlife from crossing US 6 at-grade at Heritage Road, for example, by extending the fencing around the county buildings on the northeast corner of US 6 and Heritage Road. The bike path would need to be re-routed to curve around the end of the wildlife fencing before joining the intersection. As the City of Golden is ultimately planning to replace the Heritage Road interchange with a grade-separated overpass similar to 19<sup>th</sup> Street, the fence design should be incorporated into the new interchange. CPW further recommends that the new interchange not contain any green space which may serve as an attractant for elk and other wildlife (CPW 2018).

### **Complementary Management Actions to Reduce Wildlife Conflict**

In addition to the construction of a wildlife crossing structure on US 6, several additional recommendations emerged from the discussions with to reduce wildlife conflict in the greater area around Golden. Specifically, CPW recommends (CPW 2018):

- CPW will conduct an elk collar study from Fall 2019 through 2020. The collar study will help CPW and other agencies and municipalities have a better understanding of the

current elk herd size and movement patterns and determine whether, in the future, a managed hunt could be a feasible option for controlling herd size.

- Ongoing collaboration between CPW, CDOT, the cities of Golden and Wheat Ridge, Jeffco Open Space, Denver Mountain Parks, Colorado School of Mines, and the three Golden area golf courses to determine a strategy for collaborative elk management across jurisdictional boundaries.

### **Costs of Wildlife-vehicle Collisions**

Wildlife-vehicle collisions present direct and indirect costs in terms of driver safety, collision costs, and the ecological consequences for our wildlife populations. CDOT Traffic and Safety assess the average economic costs of vehicular collisions based on the severity of the accident. The calculable costs for motor vehicle crashes used by Traffic and Safety include direct (medical costs, crash cleanup, motor vehicle damage) and indirect costs (lost productivity and wages, lost quality of life, and employer's uninsured costs). CDOT has not traditionally included estimates of the economic value of wildlife in benefit-cost analyses for wildlife mitigation projects even though hunting and wildlife watching contribute over \$5.1 billion each year to Colorado's economy (Southwick Associates 2018). A recently completed research study conducted for CDOT and CPW calculated the economic value for deer and elk using an economic contingency valuation method (Kintsch et al. 2019). While these values are still considered conservative estimates of the value of deer and elk to society, they are included in the following assessment of the cost of WVC on US 6 (Table 2).

**Table 2. Economic cost of reported WVC accidents for the last 10 years with available data (2009-2018), based on CDOT Traffic and Safety 2018 crash costs.**

<b>WVC (2009-2018)</b>			
<b>Cost Type</b>	<b>Number</b>	<b>Unit Cost</b>	<b>Total Cost</b>
Accident Type: Injury	7	\$98,900	\$692,300
Accident Type: Property Damage	104	\$10,700	\$1,112,800
Wildlife Value: Elk	64	\$2,392	\$153,088
Wildlife Value: Deer	46	\$2,061	\$94,806
Total Cost			\$2,052,994
Average Annual Cost			\$205,299

The current estimate for the mitigation improvements – including the wildlife underpass, the bike/pedestrian trail culvert, roadway realignment and bridge widening, and associated improvements – is \$12,000,000. This estimate does not include other social or environmental benefits, including the prevention of additional WVC that are not reported to law enforcement but nonetheless cause property damage, wildlife mortality and other impacts; the value of the new trail culvert and trail alignment to the community; the restoration of Kinney Run Creek; and the future cost savings derived from upgrading bridge and box culvert to accommodate six traffic lanes on US 6.

## **Conclusions**

This report documents a decade’s worth of efforts to reduce conflicts with elk and other wildlife on US 6 between 19<sup>th</sup> Street and Heritage Road. While the at-grade crosswalk and associated wildlife fencing have reduced WVC, these types of crashes continue to occur at a high rate with impacts to drivers and wildlife. CDOT and its partners evaluated multiple mitigation strategies to

reduce WVC and other wildlife conflict, resulting in the recommendation to remove the at-grade crosswalk and constructing a wildlife underpass to replace the existing double box culvert at Kinney Run (MP 273.4). The construction of a bridge underpass over Kinney Run Creek with a separate recreation trail culvert will benefit wildlife, stream health, recreationists, and driver safety.

In fall 2020, CDOT advanced design of the wildlife underpass to approximately 80 percent, and the project will be placed on the shelf until construction funding is identified. In general, shelf projects have completed most environmental clearances and are advanced as construction funding becomes available. In 2020, the City of Golden engaged a consultant team to complete the design and environmental clearances for a grade-separated interchange at US 6 and Heritage Road, similar to the one at 19<sup>th</sup> Street. This project offers a timely opportunity to align the US 6 Kinney Run wildlife crossing project with these interchange improvements. The next step for the US 6 Kinney Run wildlife crossing is to identify construction funding, finalize the design, and coordinate the construction of these two projects for the greatest cost efficiency.

## References

Caro, T. 2005. Antipredator Defenses in Birds and Mammals. The University of Chicago Press, Chicago, Illinois.

Clevenger, A.P., and M. Barrueto (eds.). 2014. Trans-Canada Highway Wildlife and Monitoring Research, Final Report. Part B: Research. Prepared for Parks Canada Agency, Radium Hot Springs, British Columbia, Canada.

Clevenger, A.P. and M.P. Huijser. 2011. Wildlife crossing structure handbook: design and evaluation in North America. Report No. FHWA-CFL/TD-11-003. Federal Highway Administration, Washington, D.C.

Colorado Parks and Wildlife (CPW). 2018. Letter to Francesca Tordonato, senior biologist, CDOT regarding CPW's comments on the proposed Kinney Run bridge along U.S. Highway 6, Golden, CO, August 1, 2018. Unpublished Document. Colorado Parks and Wildlife, Denver, CO.

Cramer, P. 2014. Wildlife crossings in Utah: Determining What Works and Helping to Create the Best and Most Cost-Effective Structure Designs. Report to Utah Division of Wildlife Resources, Salt Lake City, UT.

Cramer, P. and R. Hamlin. 2017. Evaluation of wildlife crossing structures on US 93 in Montana's Bitterroot Valley. Report No. FHWA/MT-17-003/8194. Montana Department of Transportation, Helena, MT.

Dodd, N.L., J.W. Gagnon, S. Boe, A. Manzo, and R. Schweinsburg. 2007. Evaluation of measures to minimize wildlife-vehicle collisions and maintain permeability across highways: State Route 260, Arizona, USA. Final Project Report to the Arizona Department of

Transportation, Arizona Transportation Research Center and Arizona Game and Fish Department, Phoenix, Arizona.

Donaldson, B. 2005. Use of highway underpasses by large mammals and other wildlife in Virginia and factors influencing their effectiveness. Proceedings of the 2005 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Gagnon, J.W., N.L. Dodd, S. C. Sprague, K. Ogren, and R.E. Schweinsburg. 2010. Preacher canyon wildlife fence and crosswalk enhancement project evaluation, State Route 260. Final Report No. JPA 04-088. Arizona Department of Transportation and U.S. Department of Transportation, Phoenix, AZ.

Gagnon, J.W., T.C. Theimer, N.L. Dodd, S. Boe, and R.E. Schweinsburg. 2007. Traffic volume alters elk distribution and highway crossings in Arizona. *Journal of Wildlife Management* 71(7):2318-2323.

Hedlund, H.J., P.D. Curtis, G. Curtis, A.F. Williams. 2003. Methods to reduce traffic crashes involving deer: What works and what does not. Insurance Institute for Highway Safety, Arlington, VA.

Huijser, M.P., W. Camel-Means, E.R. Fairbank, J.P. Purdum, T.D.H. Allen, A.R. Hardy, J. Graham, J.S. Begley, P. Basting, D.Becker. 2016. US 93 north post-construction wildlife-vehicle collision and wildlife crossing monitoring on the Flathead Indian Reservation between Evaro and Polson, Montana. Report Number FHWA/MT-16-009/8208. Montana Department of Transportation, Helena, MT.

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament, and P. McGowen. 2009. Cost-benefit analysis of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: a decision-support tool. *Ecology and Society* 14 (2): 15.



Huijser, M.P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith, and R. Ament. 2008. Wildlife-vehicle collision reduction study: report to Congress. Report No. FHWA-HRT-08-034. Federal Highway Administration, McLean, VA.

Kintsch, J., P. Basting, M. McClure, and J. O'Clarke. 2019. Western Slope Wildlife Prioritization Study. Report No. CDOT-2019-01. Colorado Department of Transportation, Denver, CO.

Kintsch, J. and P. Cramer. 2011. Permeability of existing structures for terrestrial wildlife: a passage assessment system. Report WA-RD 777.1 Washington Department of Transportation, Olympia, WA.

Kintsch, J., P. Cramer, P. Singer, M. Cowardin, and J. Phelan. 2019. State Highway 9 wildlife crossings monitoring year 3 progress report: December 2015 through April 2018. Study No.115.01. Colorado Department of Transportation, Applied Research and Innovation Branch, Denver, CO.

Nielsen, C.K., R.G. Anderson, and M.D. Grund. 2003. Landscape influences on deer-vehicle accident areas in an urban environment. *Journal of Wildlife Management* 67:46-51.

Riginos, C., C. Smith, E. Fairbank, E. Hansen, and P. Hallsten. 2018. Traffic thresholds in deer road-crossing behavior. Report No. WY-1807F. Wyoming Department of Transportation, Cheyenne, WY.

Rosa, S. 2006. Highway effects on small mammal communities and effectiveness of deer-vehicle collision mitigation strategy. Master's Thesis. Utah State University, Logan, UT.

Sawyer, H., C. LeBeau, and T. Hart. 2012. Mitigating roadway impacts to migratory mule deer - a case study with underpasses and continuous fencing. *Wildlife Society Bulletin* 36(3):492-498.

Servheen, C. R. Shoemaker, and L. Lawrence. 2003. A sampling of wildlife use in relation to structure variables for bridges and culverts under I-90 between Alberton and St. Regis, Montana. Proceedings of the 2003 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Southwick Associates. 2018. The 2017 Economic Contributions of Outdoor Recreation in Colorado: A Regional and County-Level Analysis. Colorado Parks and Wildlife, Denver, CO.

Ujvari, M., Baagoe, H.J., and Madsen, A.B. 2004. Effectiveness of acoustic road markings in reducing deer vehicle collisions: a behavioral study. *Wildlife Biology* 10:155-159.

Ujvari, M., Baagoe, H.J., and Madsen, A.B. 1998. Effectiveness of wildlife warning reflectors in reducing deer-vehicle collisions: a behavioral study. *Journal of Wildlife Management* 62:1094-1099.

van der Ree, R., D.J. Smith, C. Grilo (eds). 2015. *Handbook of Road Ecology*, First Edition. John Wiley and sons, Ltd., West Sussex, UK.

## Appendix A

### Acronyms

AADT	Average Annual Daily Traffic
ADS	Animal Detection System
CDOT	Colorado Department of Transportation
CPW	Colorado Parks and Wildlife
FIR	Field Inspection Review
FOR	Final Office Review
WVC	Wildlife-vehicle Collision

## Appendix B

### US Highway 6 Wildlife Crosswalk Monitoring Results



Environmental Program  
2829 W Howard Place  
Denver, CO 80204

## Memorandum

**Date:** March 17, 2020

**To:** Francesca Tordonato (CDOT Region 1 Environmental Program Manager)

**From:** Erik Schmude (CDOT Region 1 Biologist)

**Subject:** US Highway 6 Wildlife Crosswalk Monitoring (Elk) Results through December 31, 2019

### Introduction

Colorado Department of Transportation (CDOT) is conducting a wildlife crossing study in Golden, CO, along US Highway 6 (US 6). This memorandum has been prepared to summarize the results of the wildlife crossing study for the above referenced project. Although other animals use the crossing, the focus of this study is on elk (*Cervus elaphus*) due to the animal's size and potential for high hazard vehicle collisions.

### Methods

In coordination with CDOT, Pinyon Environmental, Inc. (Pinyon) biologists installed game trail cameras on each of the four corners of the wildlife crossing (two cameras on either side of the crossing, facing towards one another). Cameras one and two were installed in the southeast and northeast corners, respectively; and cameras three and four were install in the northwest and southwest corner, respectively. Data presented in the results of this memo only include data from cameras three and four because these cameras better capture the animals' failed attempts to cross the highway. Using measurements in the field and approximate camera range, a 38% overlap has been statistically calculated to adjust for double-counting individuals on both sets of camera traps. Secure digital (SD) cards were downloaded and reset approximately every month. Photos were viewed for wildlife activity. Information such as date, time, species of animal, and photo number were logged in a spreadsheet and compared with the other cameras' information.

### Results

From October, 2014 through 2019, approximately 11,330 individual elk have been observed using the wildlife crossing on US 6 (see Table 1; Graph 1; Graph 2). Further, during this time, elk have been deterred from using the wildlife crossing due to traffic on US 6. Information regarding "failed" elk crossing events are shown in Table 1 and Graph 3. As mentioned above, elk are not the only animal using the wildlife crossing. Other animals noted using the crossing include: coyote (*Canis latrans*), mule deer (*Odocoileus hemionus*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), and eastern cottontail (*Sylvilagus floridanus*). A photographic log that includes representative photos from the study is attached to further show the various animals using the crossing.

## **Attachments**

Table 1	US Highway 6 Elk Data
Graph 1	Individual Elk Crossing Data
Graph 2	Elk Crossing Event Data
Graph 3	Elk Failed Crossing Event Data
Graph 4	Precipitation Data
Graph 5	Trend in the Number of Successful Elk Crossing Events
Graph 6	Trend in the Number of Elk per Successful Crossing Event
Graph 7	2015 to 2019 Elk Crossing Summary
Graph 8	Trend in Percentage of Successful Crossings Individual Elk
Graph 9	Elk Crossing Events: October through December
Graph 10	Elk per Crossing Event: 2014 through 2019
Photographic Log	CDOT Region I Wildlife Cameras (US 6)

**Table I. US Highway 6 Elk Data**

<b>Month/Year</b>	<b>Number of Individual Elk<sup>1</sup></b>	<b>Number of Successful Crossing Events<sup>2</sup></b>	<b>Number of Failed Crossing Events<sup>3</sup></b>
October (2014)	31	7	0
November (2014)	775	45	12
December (2014)	435	29	21
January (2015)	224	18	5
February (2015)	104	7	7
March (2015)	153	17	4
April (2015)	58	20	3
May (2015)	38	11	4
June (2015)	3	2	1
July (2015)	19	6	1
August (2015)	20	6	0
September (2015)	11	7	0
October (2015)	7	3	1
November (2015)	677	46	11
December (2015)	217	10	3
January (2016)	90	9	1
February (2016)	271	13	5
March (2016)	231	20	1
April (2016)	64	7	0
May (2016)	56	3	6
June (2016)	15	6	1
July (2016)	26	12	3
August (2016)	19	3	1
September (2016)	4	2	1
October (2016)	54	9	3
November (2016)	426	25	11
December (2016)	778	28	26
January (2017)	388	23	12
February (2017)	74	7	6
March (2017)	387	16	4
April (2017)	122	14	8
May (2017)	35	11	8
June (2017)	6	3	1
July (2017)	6	3	1
August (2017)	18	3	5
September (2017)	39	11	14
October (2017)	215	18	3
November (2017)	120	18	11
December (2017)	434	16	13
January (2018)	480	13	11
February (2018)	330	11	1
March (2018)	140	5	1
April (2018)	49	3	1
May (2018)	25	6	2

Month/Year	Number of Individual Elk <sup>1</sup>	Number of Successful Crossing Events <sup>2</sup>	Number of Failed Crossing Events <sup>3</sup>
June (2018)	5	3	3
July (2018)	5	2	2
August (2018)	13	2	3
September (2018)	32	6	2
October (2018)	38	6	3
November (2018)	624	31	24
December (2018)	352	9	5
January (2019)	207	8	10
February (2019)	160	5	0
March (2019)	70	6	1
April (2019)	243	14	4
May (2019)	128	20	12
June (2019)	36	7	10
July (2019)	20	6	4
August (2019)	18	5	6
September (2019)	58	19	11
October (2019)	463	45	17
November (2019)	492	21	23
December (2019)	692	17	11
<b>Total</b>	<b>11,330</b>	<b>780</b>	<b>389</b>

Notes:

<sup>1</sup> This number represents individual elk noted using the crossing. Data calculated using a 38% overlap (percent overlap accounts for the camera view overlap between cameras 3 and 4; this helps prevent double-counting animals caught on camera).

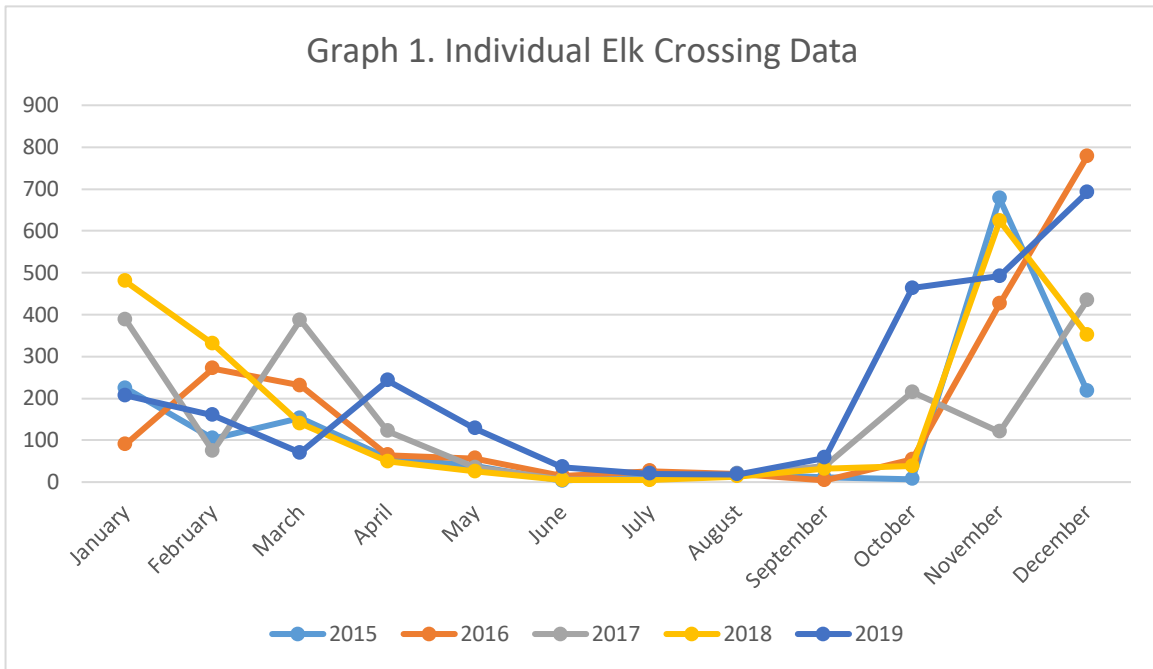
<sup>2</sup> This number represents a single elk or group of elk using the crossing. For example, one crossing event would be considered when a group of elk successfully use the crossing at the same time. A crossing event is also considered when a lone elk uses the crossing. A single crossing event may last a few seconds or up to a few hours, depending on whether or not the elk are deterred from crossing due to traffic.

<sup>3</sup> This number represents a crossing event where elk attempted to cross but fail (elk were likely deterred from crossing due to heavy traffic).

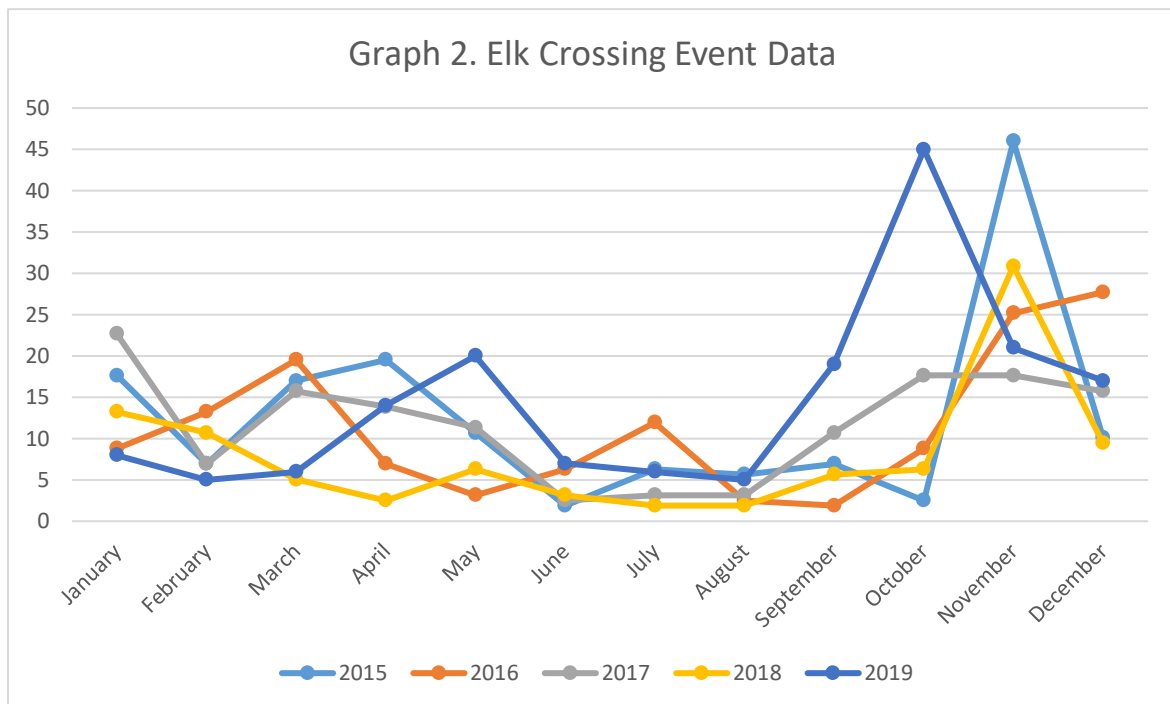
Source: CDOT data collection from Reconyx cameras 3 & 4 (westbound travel data).



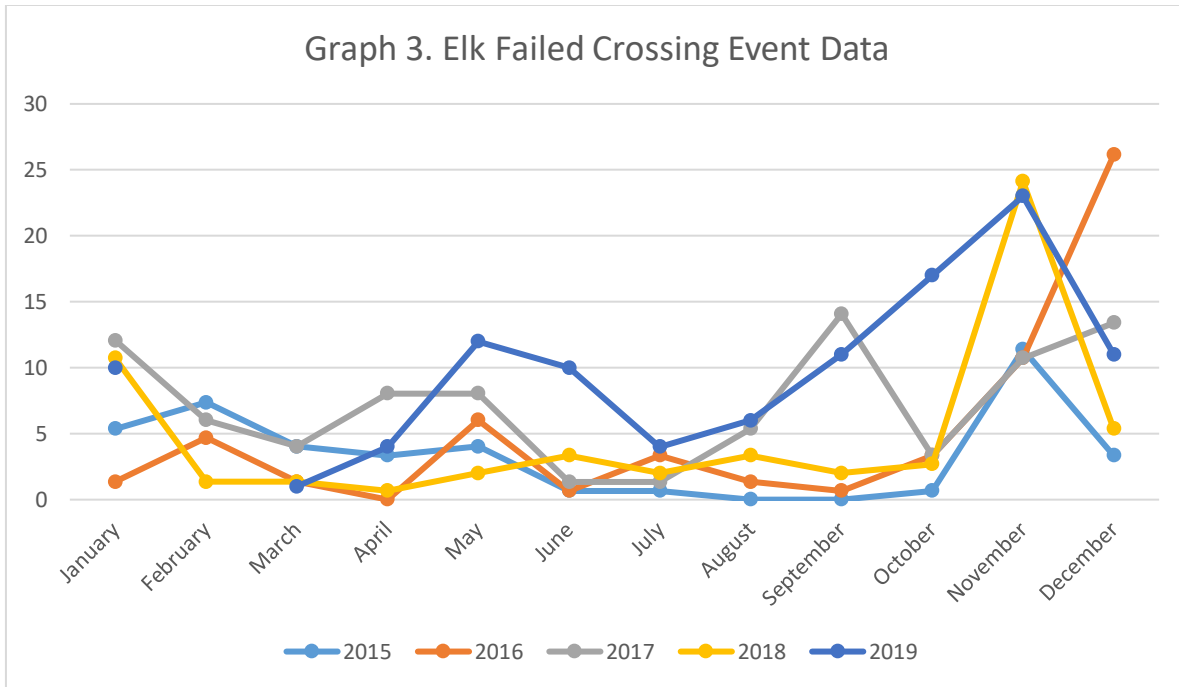
Graphs 1 through 3, below, display elk crossing data from 2015 through the end of 2019 by month. Elk activity is by far the greatest during fall and early winter with little activity during summer months.



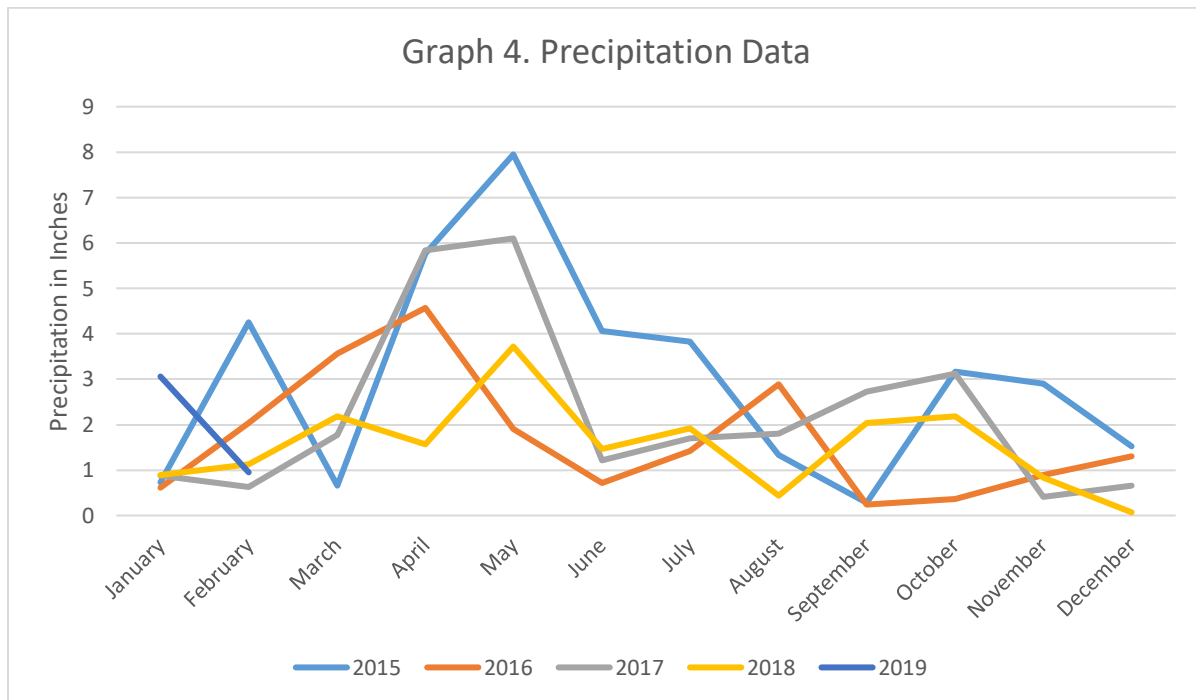
**Note:** This number represents individual elk noted using the crossing. Data calculated using a 38% overlap (percent overlap accounts for the camera view overlap between cameras 3 and 4; this helps prevent double-counting animals caught on camera).



**Note:** A crossing event is where elk (single elk or herd of elk) use the crossing at any given time. For example, one crossing event would be considered when one or more elk attempt to use the crossing at the same time. A single crossing event may last a few seconds or up to a few hours, depending on whether or not the elk are deterred from crossing due to traffic.

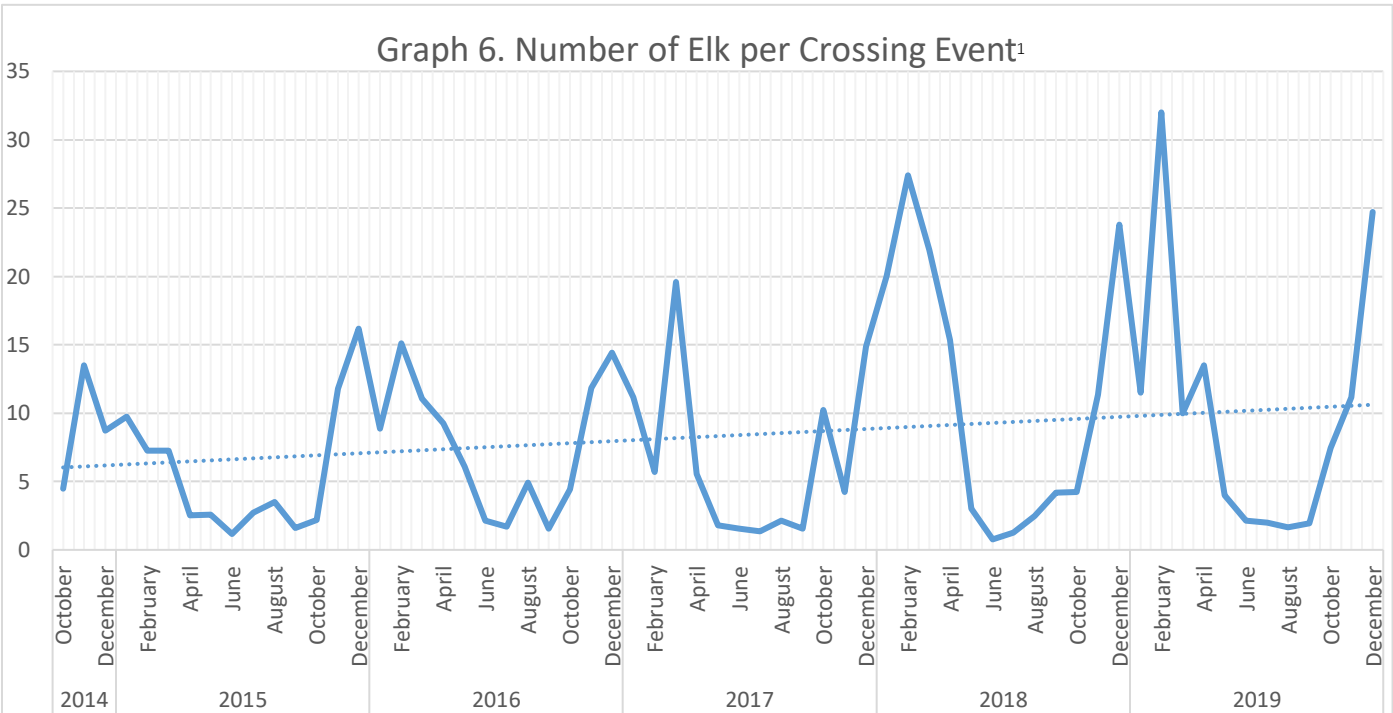
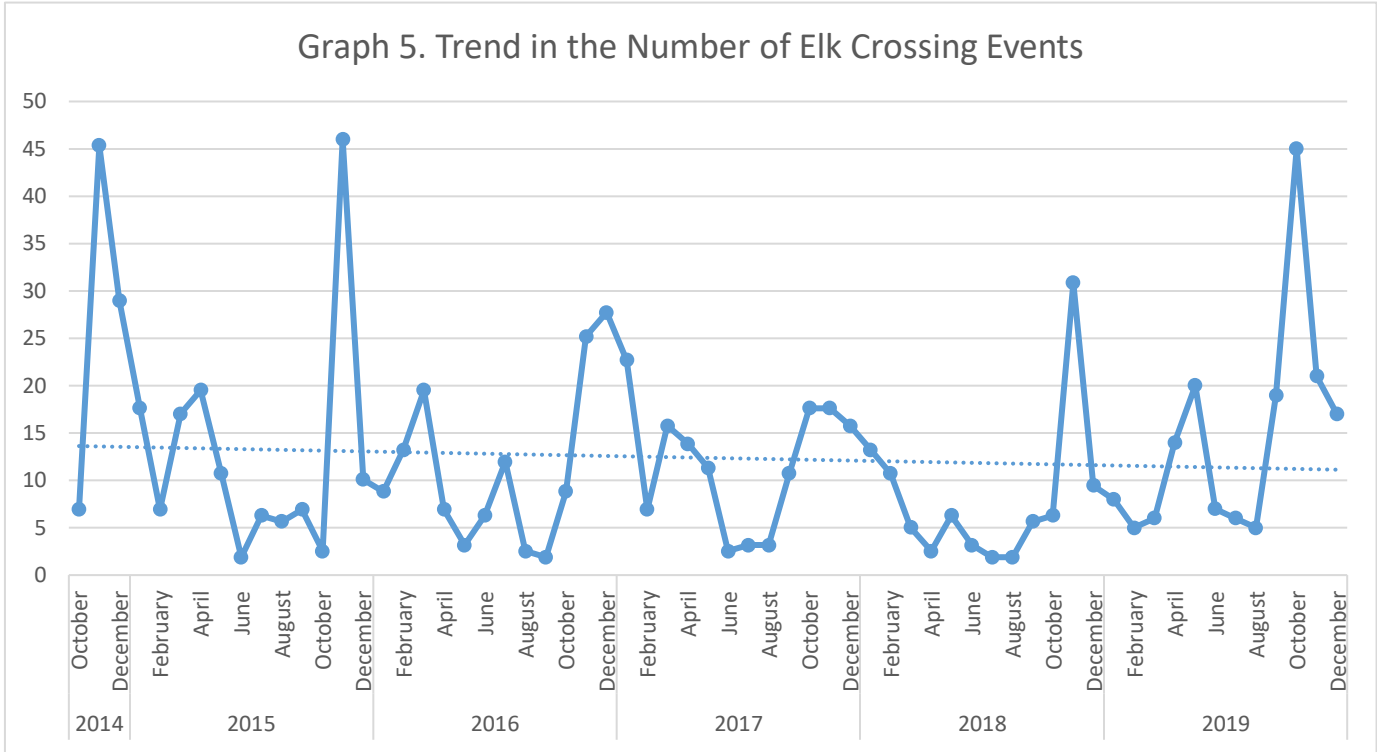


Note: This number represents a crossing event where elk attempted to cross but failed (elk were likely deterred from crossing due to heavy traffic).



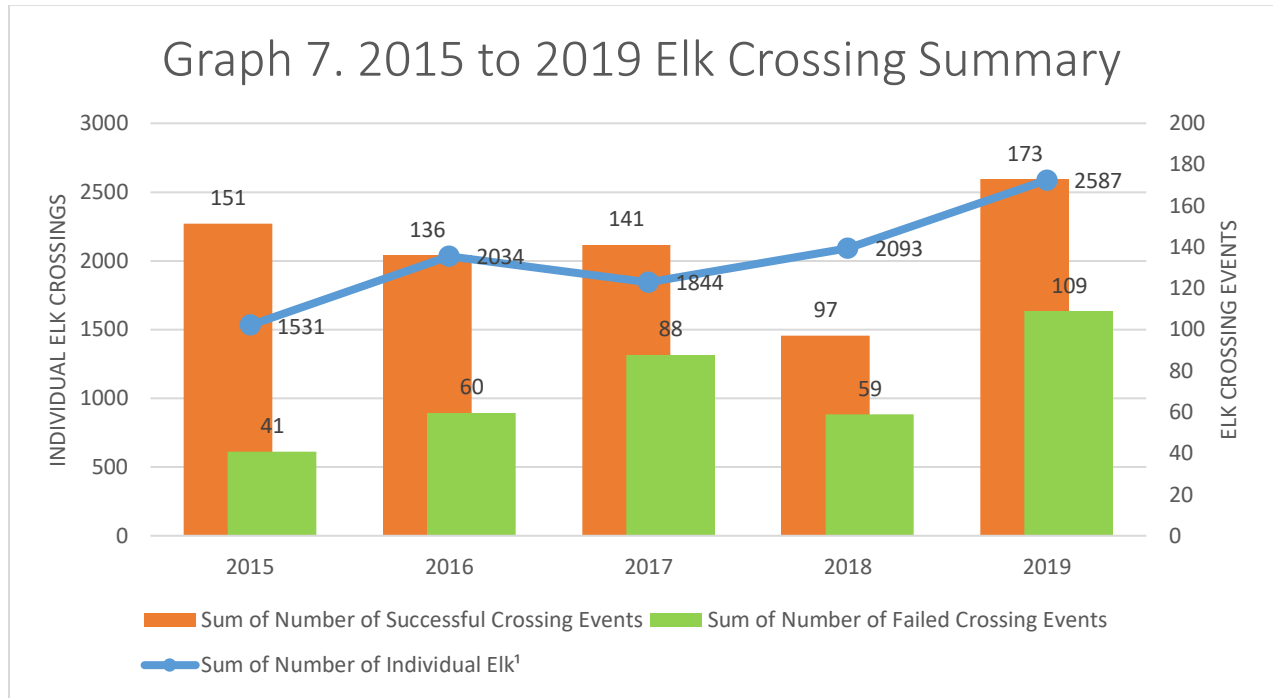
Note: This number represents the total amount of precipitation, in inches, received each month. (Source: The National Centers for Environmental Information website, <https://www.ncdc.noaa.gov>) GOLDEN 2.1 SW, CO US

The number of elk crossing events shows a weak downward trend observed from 2014 through 2019 (Graph 5) whereas the number of elk per crossing appears to have trended upwards since 2015 (Graph 6).

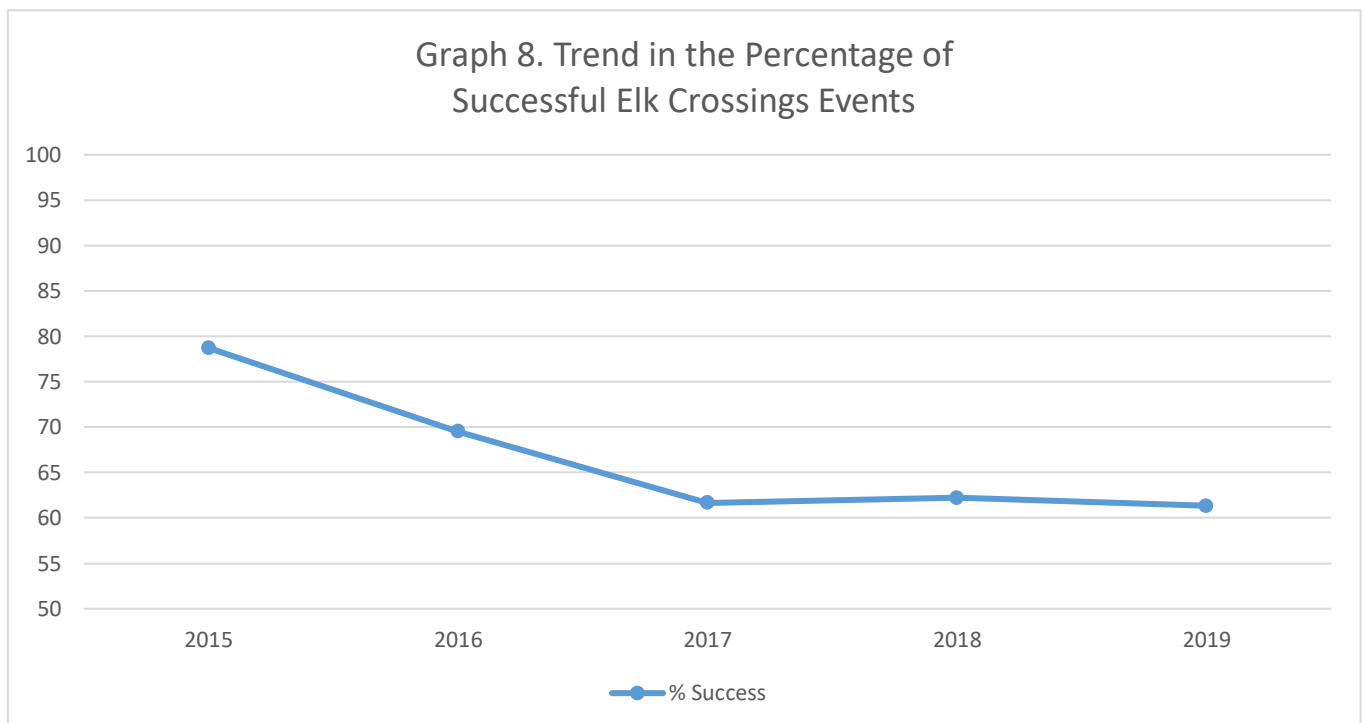


<sup>1</sup>Includes successful and fail crossing events.

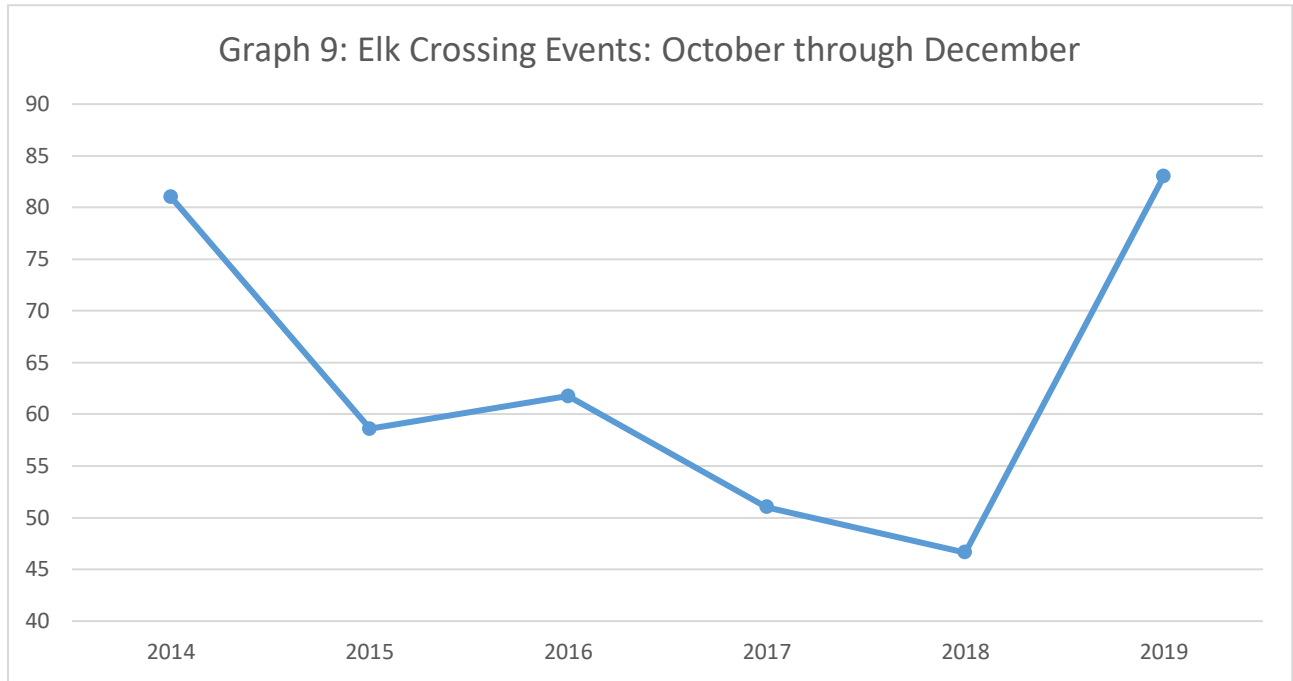
There is an increasing trend in the number of individual elk crossings since 2015 (Graph 7); however, the number of crossing events during that same time do not show a similar trend. There was a large drop in the number of crossing events (both successful and failed) in 2018 while individual elk crossings did not experience a similar drop. In fact, the number of individual elk crossings increased from 2017 to 2018.



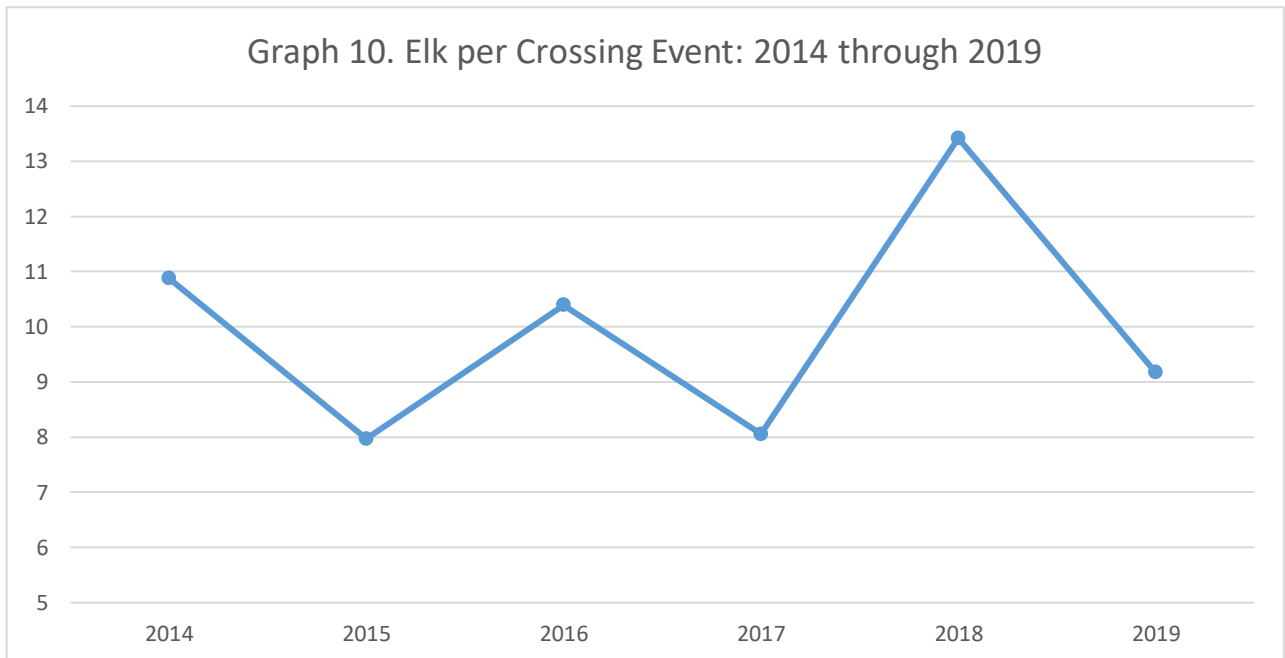
Graph 8 shows the percent of successful crossings by individual elk since 2018 which declined from 2015 to 2017 and then appeared to level in 2018 and 2019.



Graph 9 shows elk crossing events during the peak movement period of October through December (2014 to 2019). The frequency of crossings during peak months (October through December) declined from 2014 to 2018 and then sharply increased in 2019.



Graph 10 shows a spike in elk per crossing event in 2018, followed by a sharp decrease in 2019.



## Summary



- ✓ The number of individual elk crossings has trended upward since 2015.
- ✓ The number of elk per crossing event has trended upward since 2015, but sharply declined in 2019.
- ✓ The number of elk per crossing spiked in 2018.
- ✓ The frequency of October through December elk crossing events sharply increased in 2019 after having declined from 2014 to 2018



- ✓ There was a large drop in elk crossing events in 2018.
- ✓ The percentage of successful crossings by individual elk declined from 2015 to 2017 and then appeared to level off in 2018 and 2019. Overall, the percentage of successful crossings decreased from 79% in 2015 to approximately 60% between 2017 and 2019.
- ✓ Frequency of October through December elk crossing events declined from 2014 to 2018 but then sharply increased in 2019

Photo 1. Elk crossing to the west.  
Camera 1.



Photo 3. Elk with radio collar crossing to the west  
Camera 4.



---

### CDOT Region I Wildlife Cameras (US6)

Photographic Log

Photos taken between October and November 2018

Photo 3.  
Elk herd  
crossing to  
the west.  
Camera 2.



Photo 4.  
Red fox  
Camera 1.





Photo 5.  
Coyote  
crossing to  
the west  
Camera 4.



Photo 6.  
Mule deer  
crossing to  
the west.  
Camera 4.



Photo 7. Elk sparring  
Camera 4.



Photo 8. Elk crossing to the west.  
Camera 2.



## Appendix C

### US Highway 6 Wildlife Crossing Design Plans

PoDI / NHS

FHWA PROJECT OF DIVISION INTEREST (PoDI)?  NO  YES  
 NATIONAL HIGHWAY SYSTEM?  NO  YES

# DEPARTMENT OF TRANSPORTATION STATE OF COLORADO

**Related Projects:**  
 P. E. UNDER PROJECT: TAP 006A-065  
 Project Number  
 Project Code: 22028

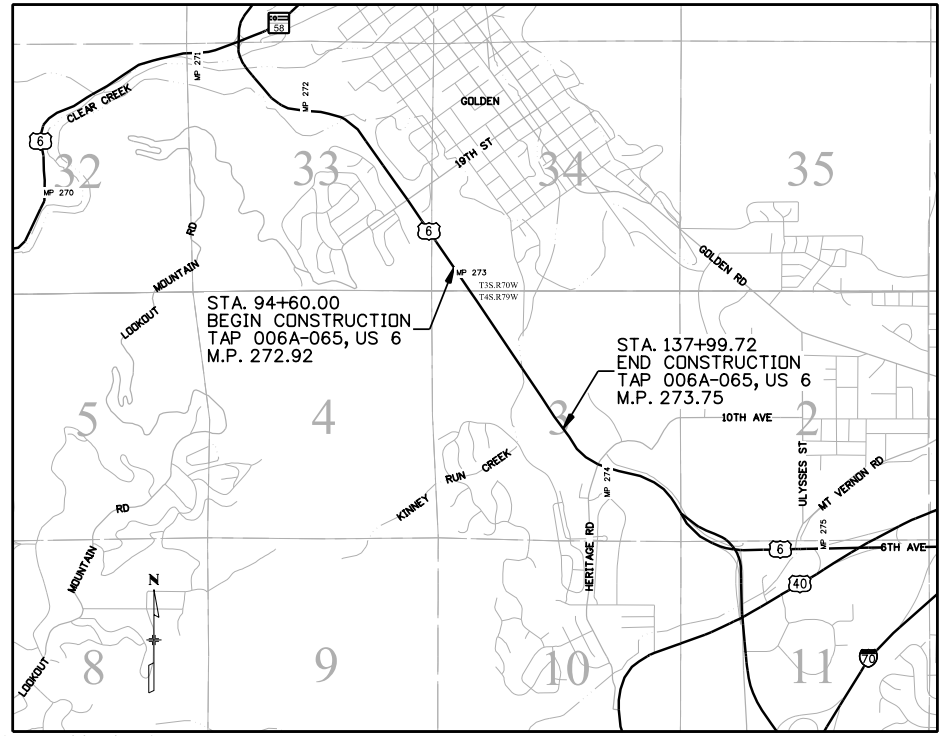
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 R.D.W. Project Description TAP 006A-065  
 XXXXXXXXXXXXXXXXXX 22028

TABULATION OF LENGTH & DESIGN DATA

STATION	FEET	FEET	
	ROADWAY US 6	MAJOR STRUCTURE	
BEGIN CONSTRUCTION STA. 94+60.00, US 6 M.P. 272.92	2,602	377	
BEGIN STRUCTURE STA. 120+62.05, US 6			
END STRUCTURE STA. 124+39.07, US 6			
END CONSTRUCTION STA. 137+99.72, US 6 M.P. 273.75	1,361		
TOTAL	3,963	377	
SUMMARY OF PROJECT LENGTH	FEET	FEET	MILES
ROADWAY (NET LENGTH)	3,963		0.75
STRUCTURE (NET LENGTH)		377	0.07
PROJECT GROSS LENGTH	4,340		0.79

HIGHWAY CONSTRUCTION BID PLANS OF PROPOSED  
**FEDERAL AID PROJECT NO. TAP 006A-065**  
 US HIGHWAY NO. 6  
**JEFFERSON COUNTY**  
 CONSTRUCTION PROJECT CODE NO. 22028

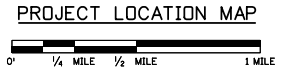
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1	TITLE SHEET
2	STANDARD PLANS LIST
3-8	TYPICAL SECTIONS
9-10	GENERAL NOTES
11-15	SUMMARY OF APPROXIMATE QUANTITIES
16-22	TABULATIONS
23-29	GEOMETRIC LAYOUT AND COORDINATE GEOMETRY
30	ELK CROSSING PLAN
31-35	ROADWAY PLANS
36	KINNEY RUN TRAIL PLAN
37-41	ROADWAY PROFILES
42-43	KINNEY RUN TRAIL PROFILE
44-74	BRIDGE PLANS STR. F-16-GA
75-78	KINNEY RUN TRAIL UNDERPASS PLANS STR. NO. 006G273476BR
79	BOX CULVERT STR. NO 006G273320BR AND WALLS TABULATION
80	BOX CULVERT EXTENSION LAYOUT STR. NO. 006G273320BR
81-88	WALL PLANS
89-91	KINNEY RUN TRAIL UNDERPASS LIGHTING PLANS STR. NO 006G273476BR
92	DRAINAGE TABULATION
93-98	KINNEY RUN TRAIL DRAINAGE AND GRADING PLANS
99	KINNEY RUN CHANNEL DRAINAGE AND GRADING PLANS
100-102	US 6 DRAINAGE DITCH AND GRADING PLANS
103	KINNEY RUN CHANNEL PROFILE
104-106	US 6 DRAINAGE DITCH PROFILE
107-108	DRAINAGE PIPE PROFILES
109-112	WATER QUALITY PLANS
113-122	KINNEY RUN CREEK STILLING BASIN PLANS
123-150	SWMP PLANS
151-152	MITIGATION AND LANDSCAPE PLANS
153-167	UTILITY PLANS
168-169	WATERLINE PLANS
170-179	SIGNING AND STRIPING PLANS
180-200	PHASING PLANS
201-221	US 6 CROSS SECTIONS
222-224	KINNEY RUN TRAIL CROSS SECTIONS
225-227	KINNEY RUN CHANNEL CROSS SECTIONS
228-236	US 6 DRAINAGE DITCH CROSS SECTIONS
01-04	SUE PLANS



DESIGN DATA	US 6
MAXIMUM RADIUS OF CURVE	12,900
MAXIMUM GRADE	5.57%
MINIMUM S.S.D. HORIZONTAL	1,283'
MINIMUM S.S.D. VERTICAL	273'
MAXIMUM DESIGN SPEED	65 MPH
2018 DESIGN TRAFFIC	DHV = 2,970 ADT = 33,000
2040 DESIGN TRAFFIC	DHV = 3,558 ADT = 39,534
DHV TRUCKS	4.5%
CLEAR ZONE DISTANCE (TANGENT)	30 FT
CONSTRUCTION CLEAR ZONE	30 FT

**EXCERPTED FROM**  
**FOR SUBMITTAL**  
**OCTOBER 27, 2020**

For "US Highway 6 Wildlife-Highway Mitigation Assessment",  
 November 2020  
 Full package available from CDOT Region 1, Central Engineering



Print Date: Monday, October 12, 2020 12:06:46 PM  
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 6220 - R1 CENTRAL STS

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation  
 Region 1 STS  
 2829 W Howard Place  
 Denver, CO. 80204  
 Phone: 303-512-5986  
 Fax: 303-757-9099

**As Constructed**  
 No Revisions:  
 Revised:  
 Void:

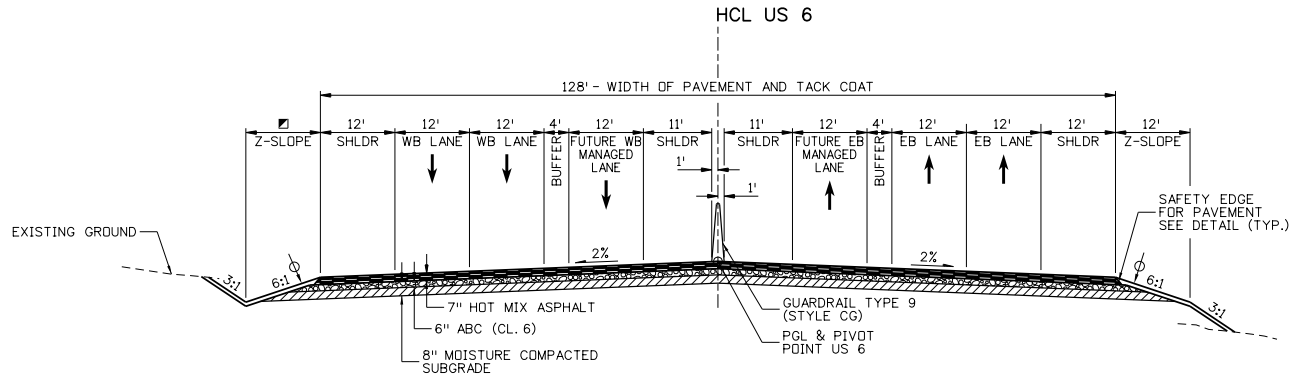
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Contractor:	
Resident Engineer:	
Project Engineer:	
PROJECT STARTED: / /	ACCEPTED: / /
Comments:	

**Project No./Code**  
 TAP 006A-065  
 22028  
 Sheet Number **1**

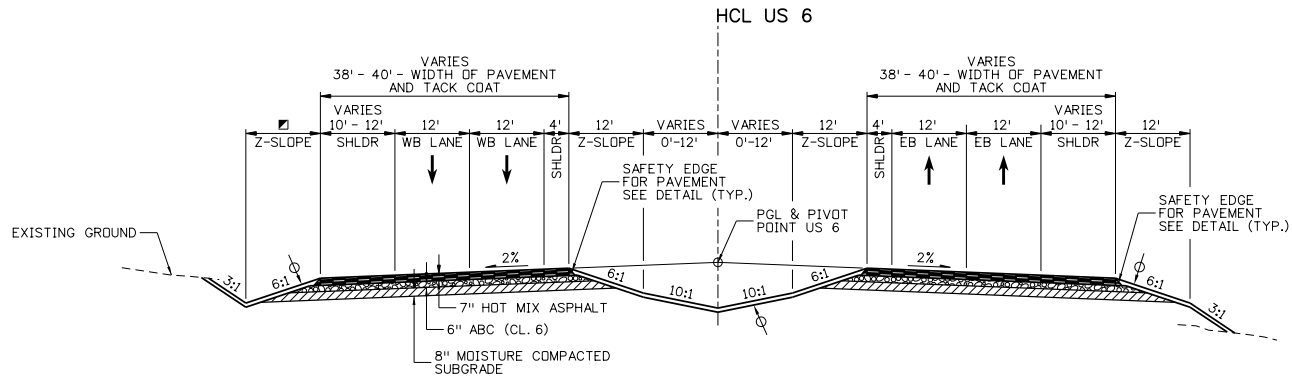
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Know what's below.  
Call before you dig.



US 6  
STA. 120+62.05 TO STA. 124+39.07



US 6  
STA. 109+00.00 TO STA. 120+62.05  
STA. 124+39.07 TO STA. 134+25.73

☑ Z-SLOPE LEFT

STA. 109+00 TO STA. 114+00	- 4'
STA. 114+00 TO STA. 115+00	- 4'-8"
STA. 115+00 TO STA. 120+60	- 8'
STA. 120+60 TO STA. 134+25.73	- 12'

**NOTES:**

1. TYPICAL SECTIONS ARE REPRESENTATIVE ONLY. PLAN SHEETS ARE TO BE USED FOR CONSTRUCTION.
  2. BREAK POINT ON SLOPES AND IN BOTTOMS OF DITCHES SHALL BE ROUNDED DURING CONSTRUCTION.
  3. ALL EMBANKMENT MATERIAL SHALL HAVE AN R-VALUE = 20 OR GREATER.
- ∅ = MINIMUM 4" TOPSOIL

- 2" HMA (GRADING SX) (100) (PG 76-28)
- 2.5" HMA (GRADING S) (100) (PG 64-22)
- 2.5" HMA (GRADING S) (100) (PG 64-22)



7 INCH ASPHALT PAVEMENT DETAIL

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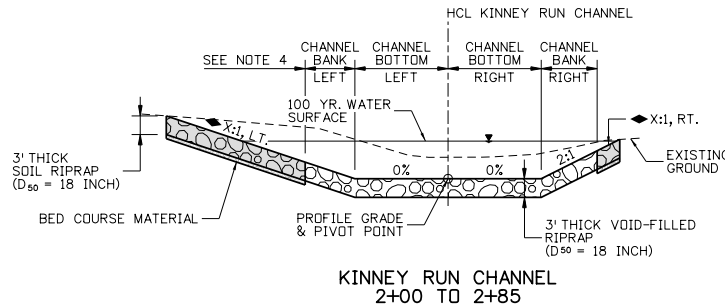
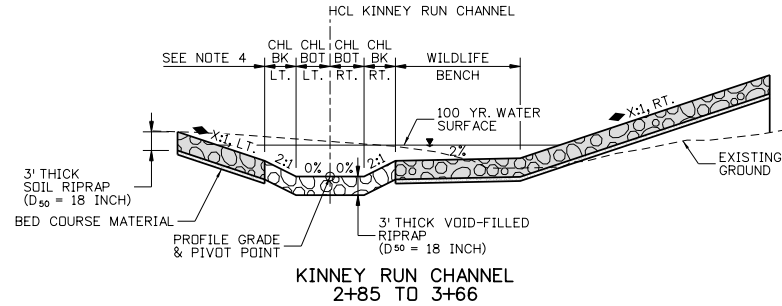
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1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139					STS		Void:		Designer: M. GRANT Detailer: D. MADDOCK Sheet Subset: TYPICAL		Sheet Number
							Structure Numbers		Subset Sheets: 1 of 6		3



Know what's below.  
Call before you dig.

**NOTES:**

1. SEE KINNEY RUN CHANNEL PROFILE AND GRADING PLANS FOR ADDITIONAL INFORMATION.
2. SEE KINNEY RUN CHANNEL STILLING BASIN DETAILS FOR ADDITIONAL INFORMATION.
3. SEE RIPRAP, SOIL RIPRAP AND VOID FILLED RIPRAP DETAILS FOR ADDITIONAL INFORMATION.
4. SEE KINNEY RUN TYPICAL SECTIONS DATA SHEET FOR WIDTHS AND SLOPES.

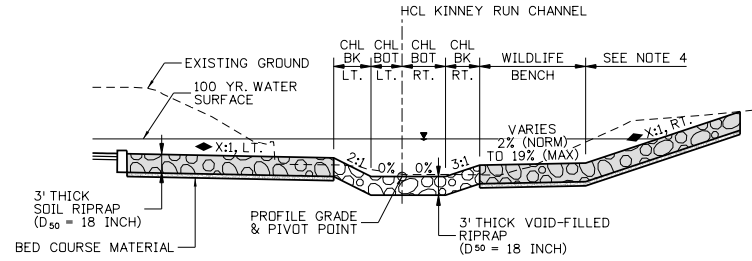


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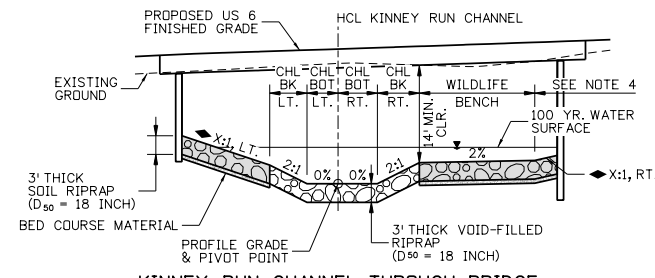
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1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139					STS		Void:		Sheet Subset: TYPICAL		Structure Numbers	
									Sheet Subset: TYPICAL		Subset Sheets: 3 of 6	
											Sheet Number 5	



Know what's below.  
Call before you dig.



KINNEY RUN CHANNEL  
5+14 TO 6+96.33



KINNEY RUN CHANNEL THROUGH BRIDGE  
3+66 TO 5+14

- NOTES:**
1. SEE KINNEY RUN CHANNEL PROFILE AND GRADING PLANS FOR ADDITIONAL INFORMATION.
  2. SEE KINNEY RUN CHANNEL STILLING BASIN DETAILS FOR ADDITIONAL INFORMATION.
  3. SEE RIPRAP, SOIL RIPRAP AND VOID FILLED RIPRAP DETAILS FOR ADDITIONAL INFORMATION.
  - ◆ 4. SEE KINNEY RUN TYPICAL SECTIONS DATA SHEET FOR WIDTHS AND SLOPES.

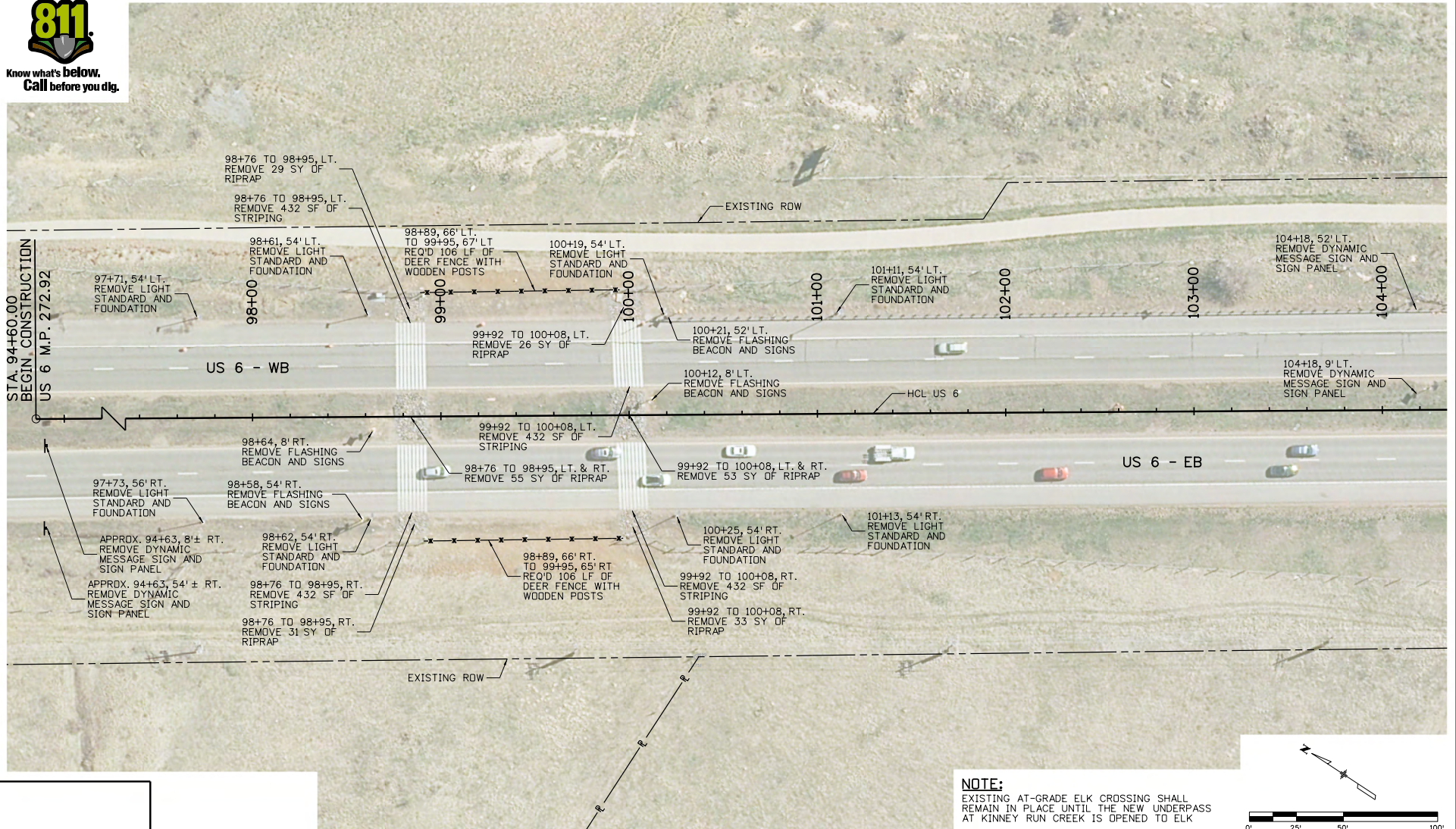
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Horiz. Scale: 1:20	Vert. Scale: As Noted					Revised:				Structure Numbers	
 1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139					Region 1	Void:		Sheet Subset: TYPICAL		Subset Sheets: 4 of 6	
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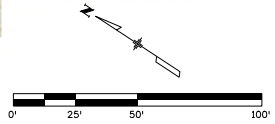


Know what's below.  
Call before you dig.

STA. 94+60.00  
BEGIN CONSTRUCTION  
US 6 M.P. 272.92



**NOTE:**  
EXISTING AT-GRADE ELK CROSSING SHALL REMAIN IN PLACE UNTIL THE NEW UNDERPASS AT KINNEY RUN CREEK IS OPENED TO ELK



Print Date: Monday, October 12, 2020 12:15:12 PM		Sheet Revisions		Colorado Department of Transportation		As Constructed		US 6 WILDLIFE CROSSING REMOVAL OF EXISTING AT-GRADE ELK CROSSING		Project No./Code	
File Name: 22028_DES_ElkCrossing01.dgn		Date:	Comments	Init.		No Revisions:		Designer: M. GRANT Detailer: D. MADDOCK		TAP 006A-065	
Horiz. Scale: 1:50	Vert. Scale: As Noted					Revised:				Structure Numbers	
1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139							Sheet Subset: ROADWAY Subset Sheets: 1 of 14		Sheet Number 30		
					Region 1		STS				

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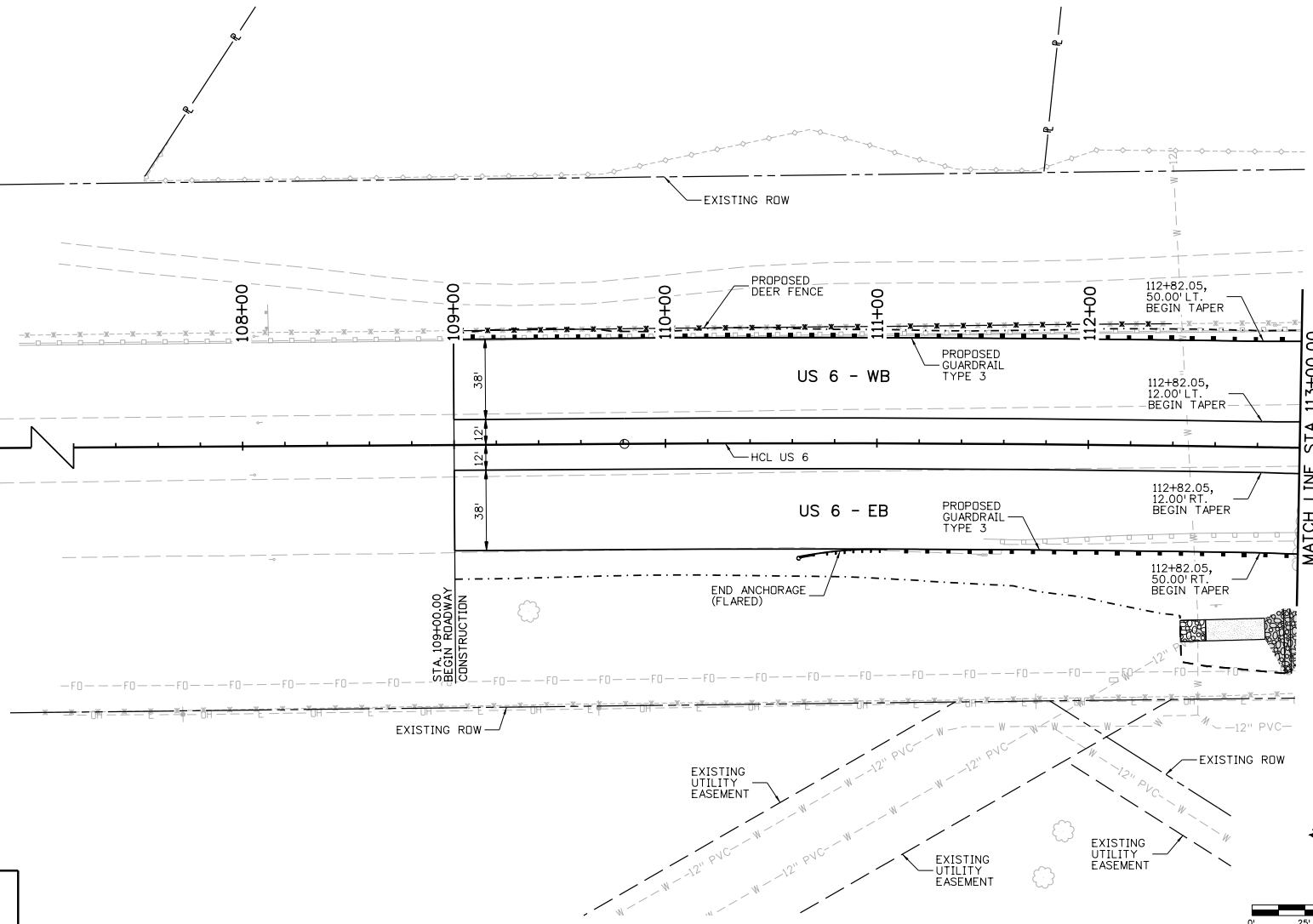




Know what's below.  
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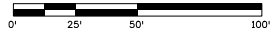
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STA. 94+60.00  
BEGIN CONSTRUCTION  
US 6 M.P. 272.92



MATCH LINE STA. 113+00.00

- LEGEND:**
- VOID-FILLED RIPRAP
  - SOIL RIPRAP
  - WETLAND IMPACTS
  - SB 40 SHRUBS
  - SB 40 SHRUBS IMPACTS



Print Date: Monday, October 12, 2020 12:15:15 PM  
 File Name: 22028\_DES\_Roadway\_Plan01.dgn  
 Horiz. Scale: 1:50 Vert. Scale: As Noted

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation  
 Region 1

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As Constructed	No Revisions:
Revised:	
Void:	

**US 6 WILDLIFE CROSSING ROADWAY PLAN**  
 94+60.00 TO 113+00.00

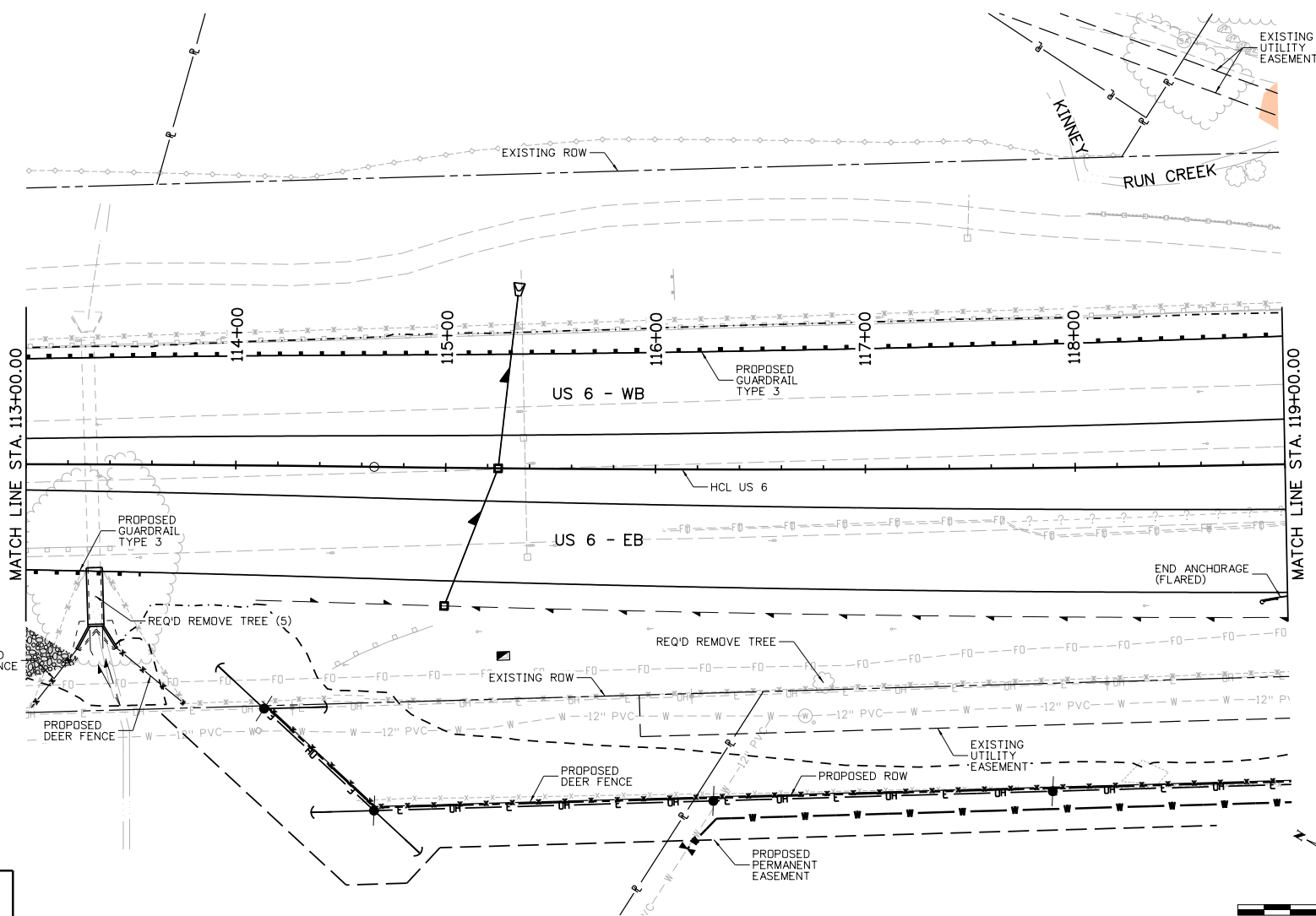
Designer: M. GRANT  
 Detailer: D. MADDCK

Structure Numbers  
 Sheet Subset: ROADWAY Subset Sheets: 2 of 14

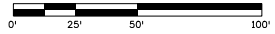
Project No./Code	TAP 006A-065
	22028
Sheet Number	31



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Print Date: Monday, October 12, 2020 12:15:17 PM  
 File Name: 22028\_DES\_Roadway\_Plan02.dgn  
 Horiz. Scale: 1:50 Vert. Scale: As Noted

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 1670 BROADWAY, SUITE 3400  
 DENVER, COLORADO 80202  
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Sheet Revisions		
Date:	Comments	Init.

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STS

As Constructed	No Revisions:
Revised:	
Void:	

**US 6 WILDLIFE CROSSING ROADWAY PLAN**  
 113+00.00 TO 119+00.00

Designer: M. GRANT  
 Detailer: D. MADDOCK

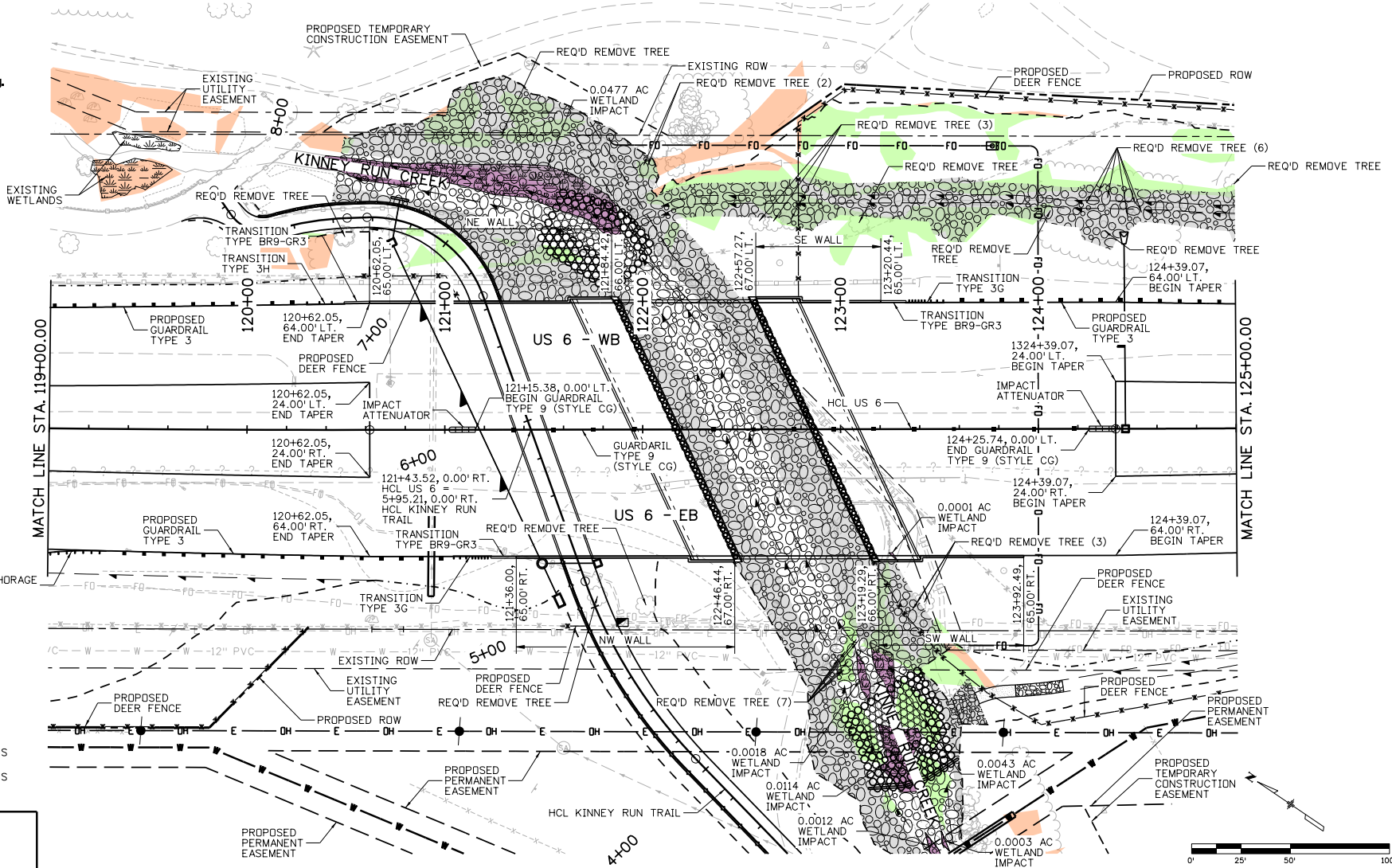
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Project No./Code	TAP 006A-065
	22028
Sheet Number	32

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Print Date: Monday, October 12, 2020 12:15:20 PM  
 File Name: 22028\_DES\_Roadway\_Plan03.dgn  
 Horiz. Scale: 1:50 Vert. Scale: As Noted

Sheet Revisions			
Date:	Comments	Init.	

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Region 1 STS

As Constructed
No Revisions:
Revised:
Void:

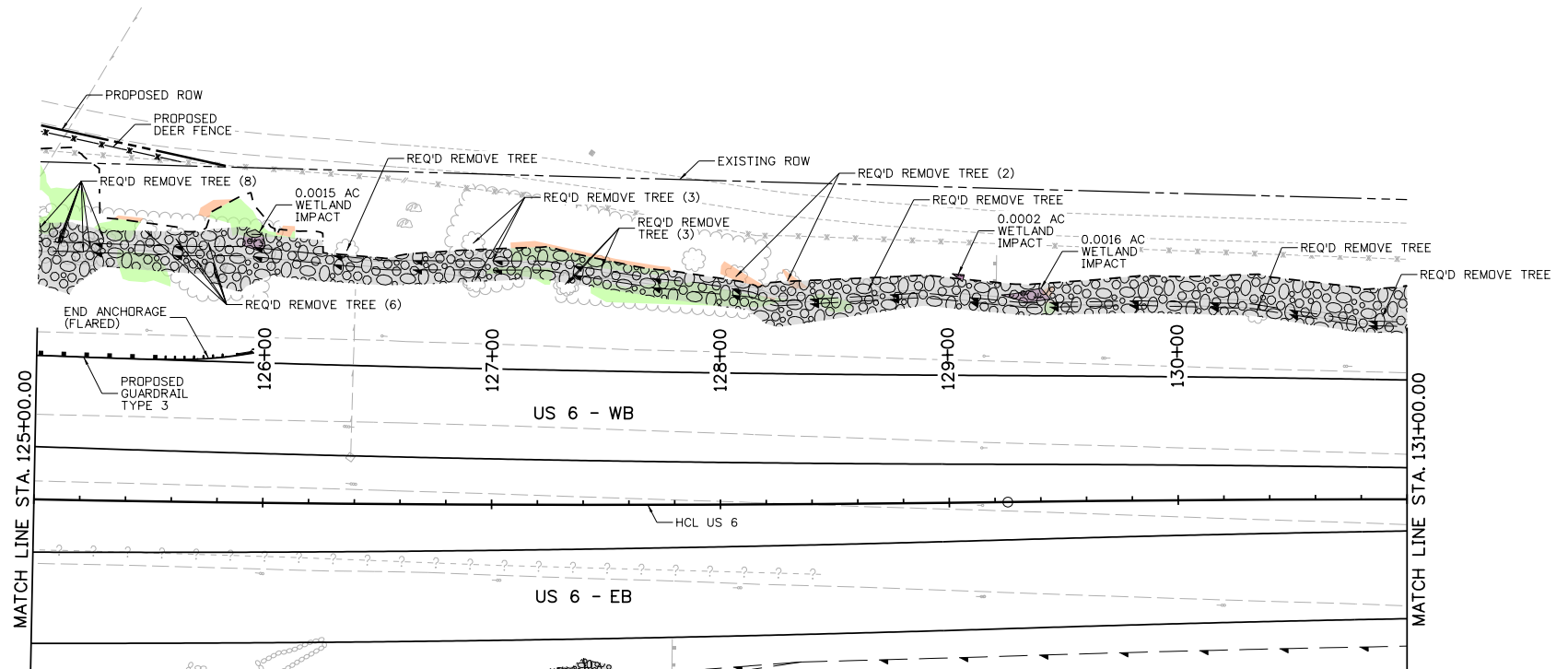
US 6 WILDLIFE CROSSING ROADWAY PLAN 119+00.00 TO 125+00.00			
Designer:	M. GRANT	Structure Numbers	
Detailer:	D. MADDOCK		
Sheet Subset:	ROADWAY	Subset Sheets:	4 of 14

Project No./Code
TAP 006A-065
22028
Sheet Number 33

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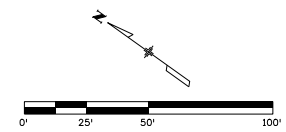
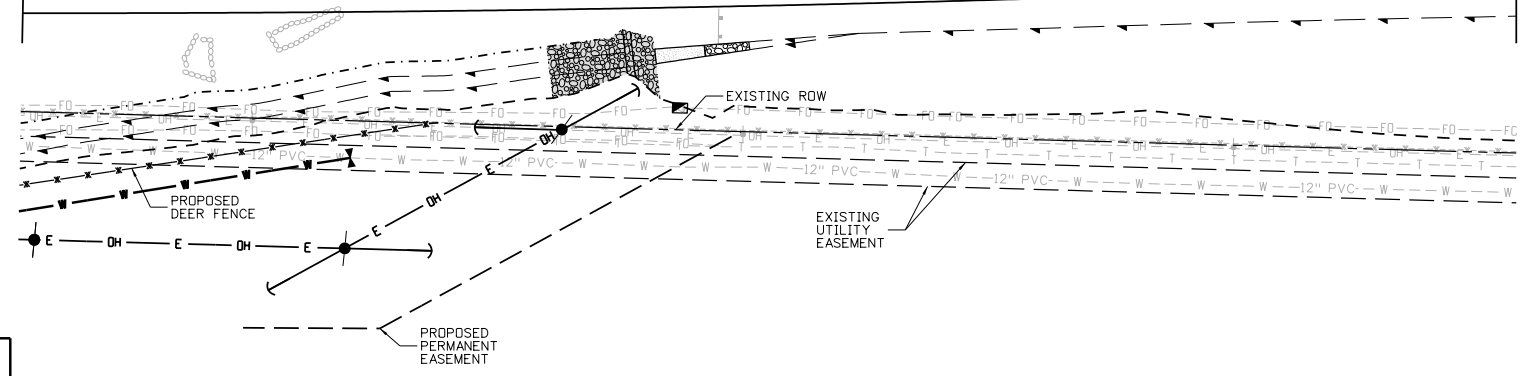


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**LEGEND:**

- VOID-FILLED RIPRAP
- SOIL RIPRAP
- WETLAND IMPACTS
- SB 40 SHRUBS
- SB 40 SHRUBS IMPACTS



Print Date: Monday, October 12, 2020 12:15:24 PM		<b>Sheet Revisions</b>		<b>Colorado Department of Transportation</b>		<b>As Constructed</b>		<b>US 6 WILDLIFE CROSSING ROADWAY PLAN</b>		<b>Project No./Code</b>	
File Name: 22028_DES_Roadway_Plan04.dgn		Date:	Comments:	Init.	 2829 W Howard Place Denver, CO. 80204 Phone: 303-512-5986 Fax: 303-757-9099	No Revisions:		<b>125+00.00 TO 131+00.00</b>		TAP 006A-065	
Horiz. Scale: 1:50    Vert. Scale: As Noted						Revised:	Designer: M. GRANT	Structure Numbers:	22028		
 1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139						Void:	Detailer: D. MADDOCK	Sheet Subset: ROADWAY		Subset Sheets: 5 of 14	
						<b>Region 1</b>		<b>STS</b>		Sheet Number <b>34</b>	

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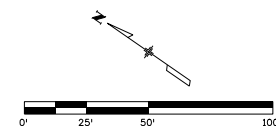
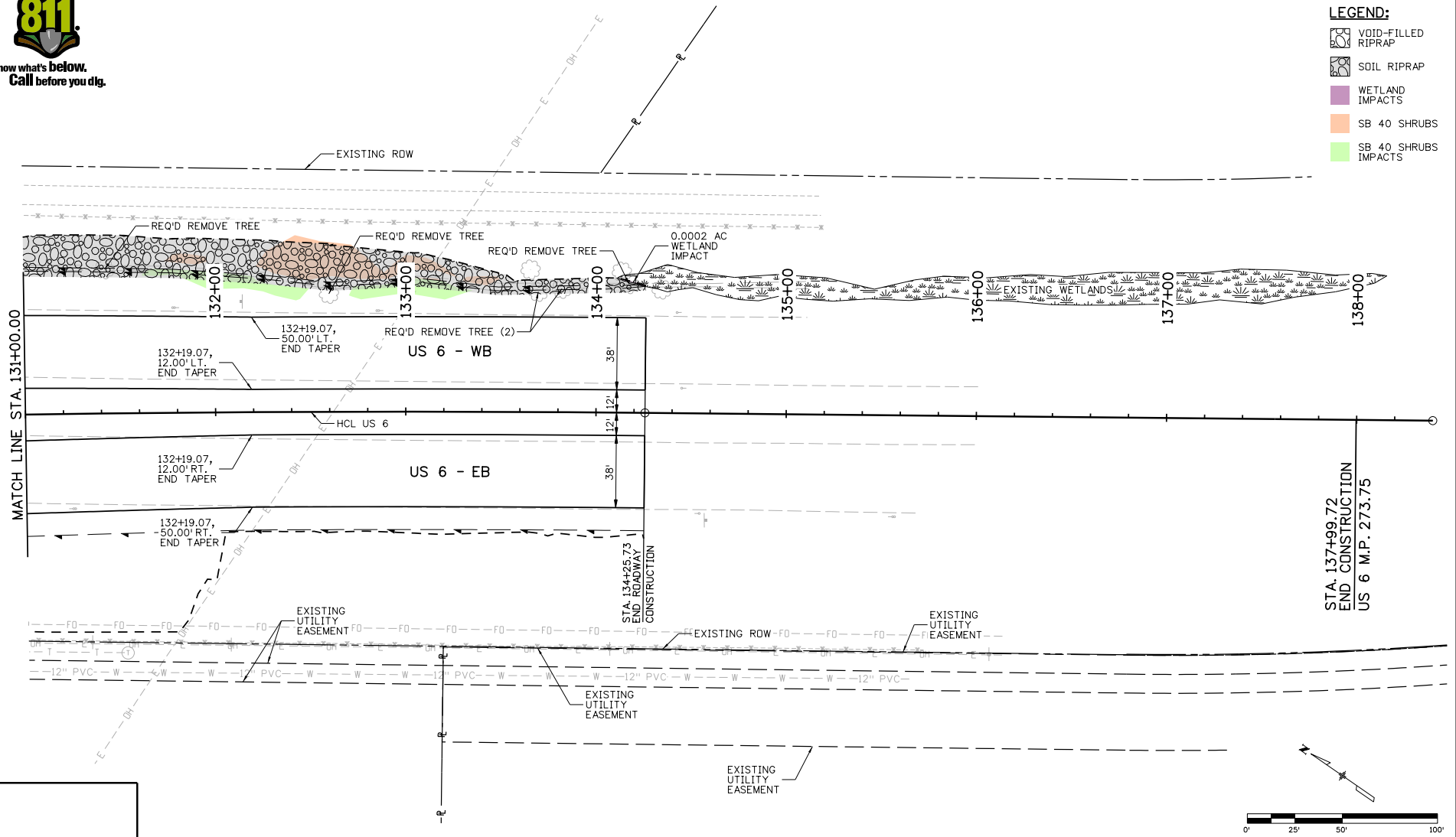


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- SB 40 SHRUBS
- SB 40 SHRUBS IMPACTS

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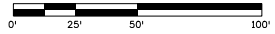
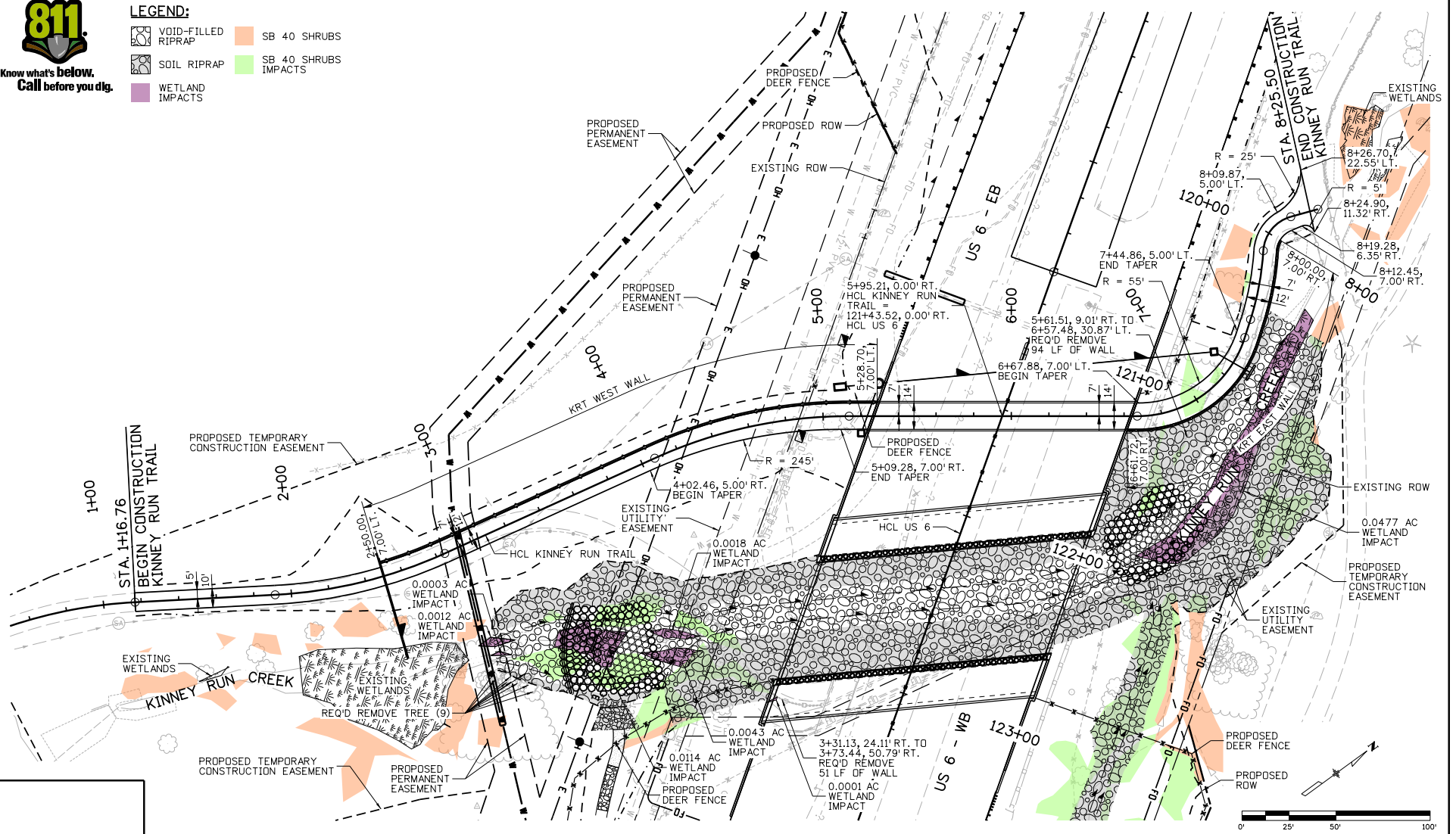
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File Name: 22028_DES_Roadway_Plan05.dgn		Date:	Comments	Init.	 2829 W Howard Place Denver, CO, 80204 Phone: 303-512-5986 Fax: 303-757-9099	No Revisions:		131+00.00 TO 138+40.00		TAP 006A-065	
Horiz. Scale: 1:50	Vert. Scale: As Noted					Revised:	Designer: M. GRANT	Structure Numbers:	22028		Sheet Number
 1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139					Region 1	Void:	Sheet Subset: ROADWAY	Subset Sheets: 6 of 14	35		



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-  WETLAND IMPACTS
-  SB 40 SHRUBS
-  SB 40 SHRUBS IMPACTS



Print Date: Monday, October 12, 2020 12:15:29 PM  
 File Name: 22028\_DES\_Roadway\_Plan06.dgn  
 Horiz. Scale: 1:50 Vert. Scale: As Noted

Sheet Revisions		
Date:	Comments	Init.

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Region 1 STS

As Constructed	No Revisions:
Revised:	
Void:	

US 6 WILDLIFE CROSSING KINNEY RUN TRAIL PLAN		
Designer:	M. GRANT	Structure Numbers
Detailer:	D. MADDOCK	
Sheet Subset:	ROADWAY	Sheet Sheets: 7 of 14

Project No./Code	TAP 006A-065
	22028
Sheet Number	36

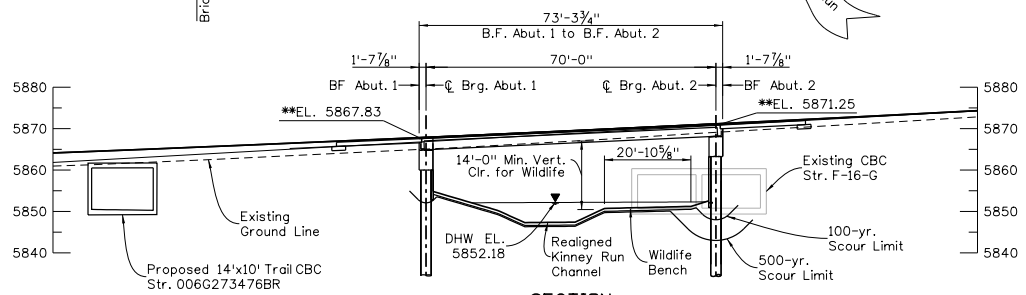
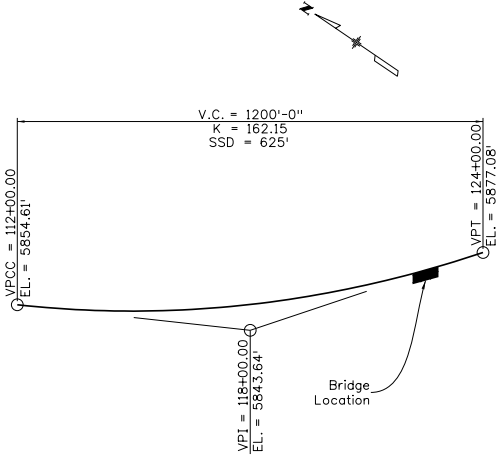
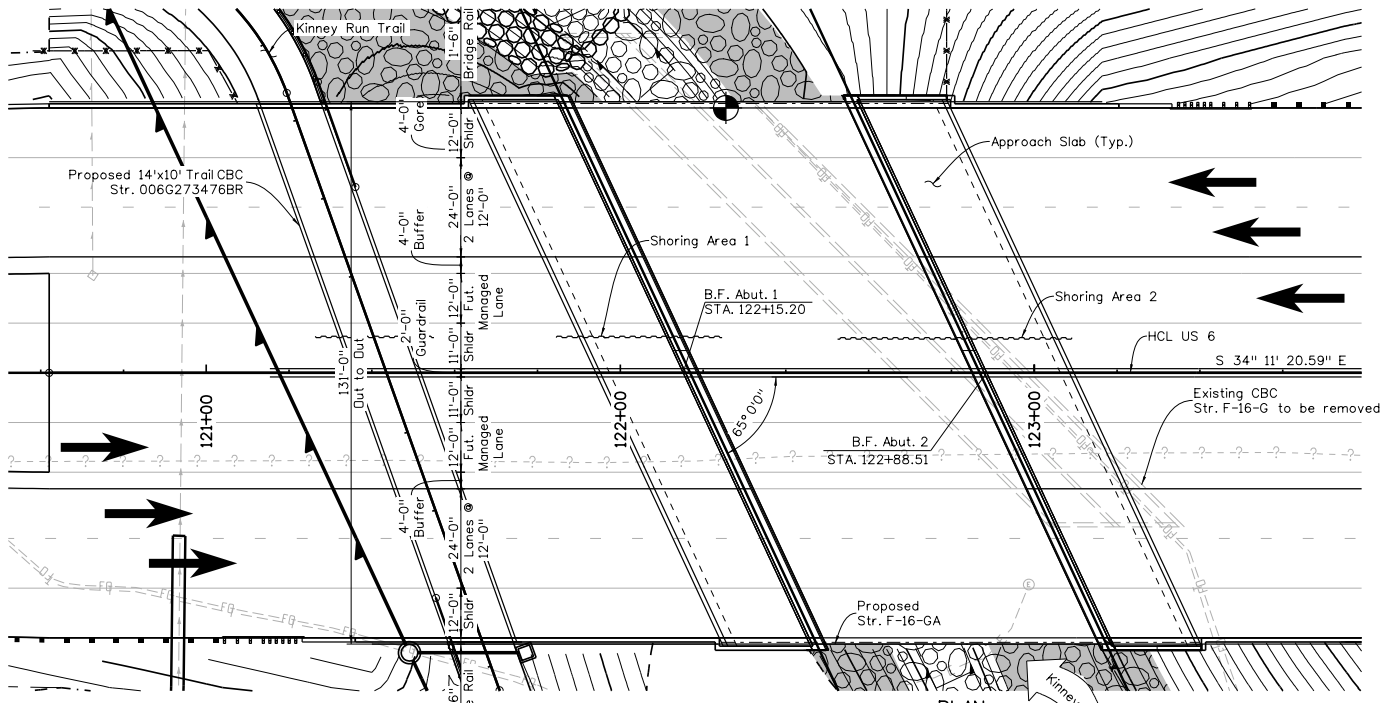
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mascorenas 3/08/20 PM p:\1\CDOT\APPS\6.dot\state.co.us\p\geoproduction\Documents\Projects\22020-22998\000-098\20208 - us wildlife crossing and trail\bridge\Drawings\22020BRDG\_B03\_General Layout

INITIALS	DESIGN	DATE	DETAIL	QUANTITY	DATE
AMM	08/20	AMM	08/20	AMM	08/20
MCY	08/20	MCY	08/20	MCY	08/20



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\*\*Elevations at Finished Grade

SECTION  
Taken at HCL/PGL US 6

Point of Minimum Vertical Clearance at Wildlife Bench

Print Date: 10/9/2020
File Name: 22028BRDG_B03 General Layout
Horiz. Scale: 1:1      Vert. Scale: As Noted
Staff Bridge Branch - Unit 0224      MSZ

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation

2829 W Howard Place  
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Region 1      STS

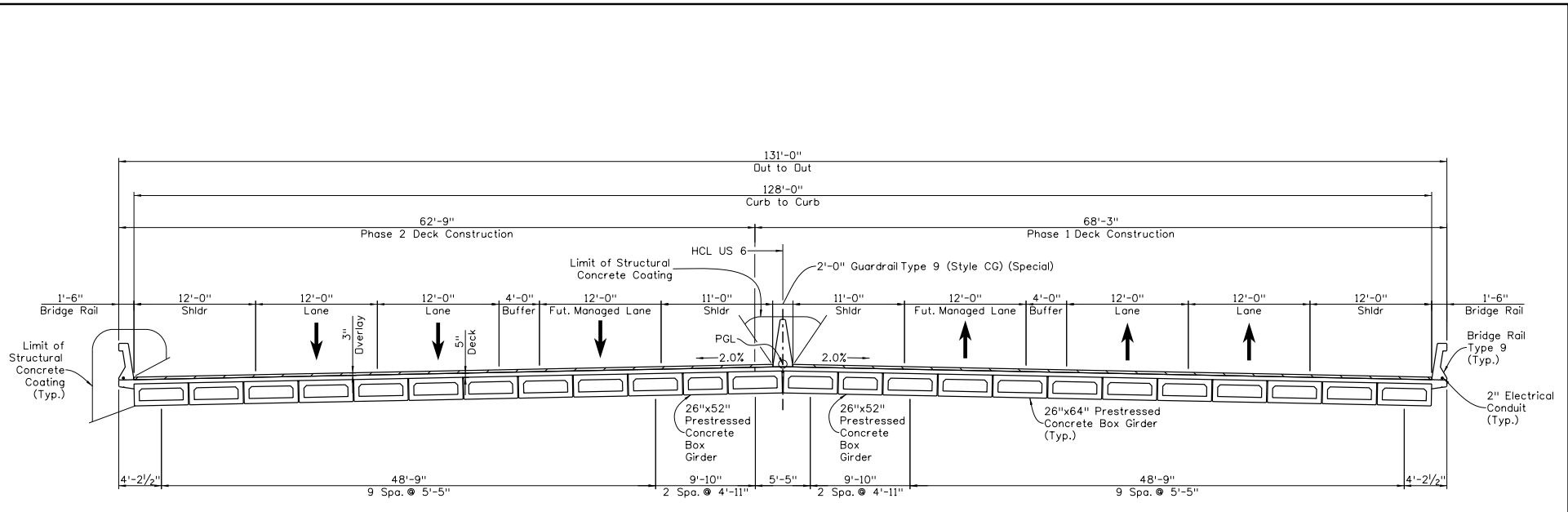
As Constructed
No Revisions:
Revised:
Void:

US 6 - WILDLIFE CROSSING GENERAL LAYOUT			
Designer: A. Mascarenas	Structure Numbers	F-16-GA	-
Detailer: A. Mascarenas	Sheet Subset: Bridge	Subset Sheets: B03 of 31	

Project No./Code	TAP 006A-065
Sheet Number	46

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INITIALS	DESIGN	DATE	DETAIL	DATE	QUANTITY	DATE
AMM	AMM	08/20	AMM	08/20	AMM	08/20
MCY	MCY	08/20	MCY	08/20	MCY	08/20



**TYPICAL SECTION**  
(Looking East)

Print Date: 10/9/2020  
 File Name: 22028BRDG\_B04 Typical Section  
 Horiz. Scale: 1:1      Vert. Scale: As Noted  
 Staff Bridge Branch - Unit 0224      MSZ

Sheet Revisions		
Date:	Comments	Init.

Colorado Department of Transportation  
 Region 1



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STS

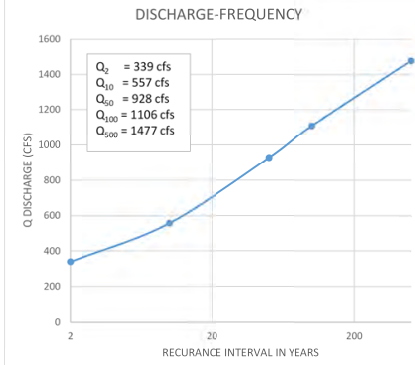
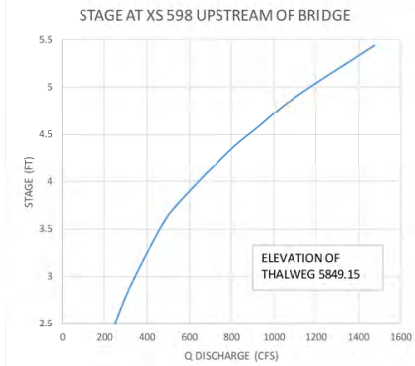
<b>As Constructed</b>
No Revisions:
Revised:
Void:

<b>US 6 - WILDLIFE CROSSING</b>			
<b>TYPICAL SECTION</b>			
Designer:	A. Mascarenas	Structure Numbers:	F-16-GA
Detailer:	A. Mascarenas	Sheet Subset:	Bridge
Subst Sheets:	B04	of 31	

<b>Project No./Code</b>
TAP 006A-065
22028
Sheet Number <b>47</b>



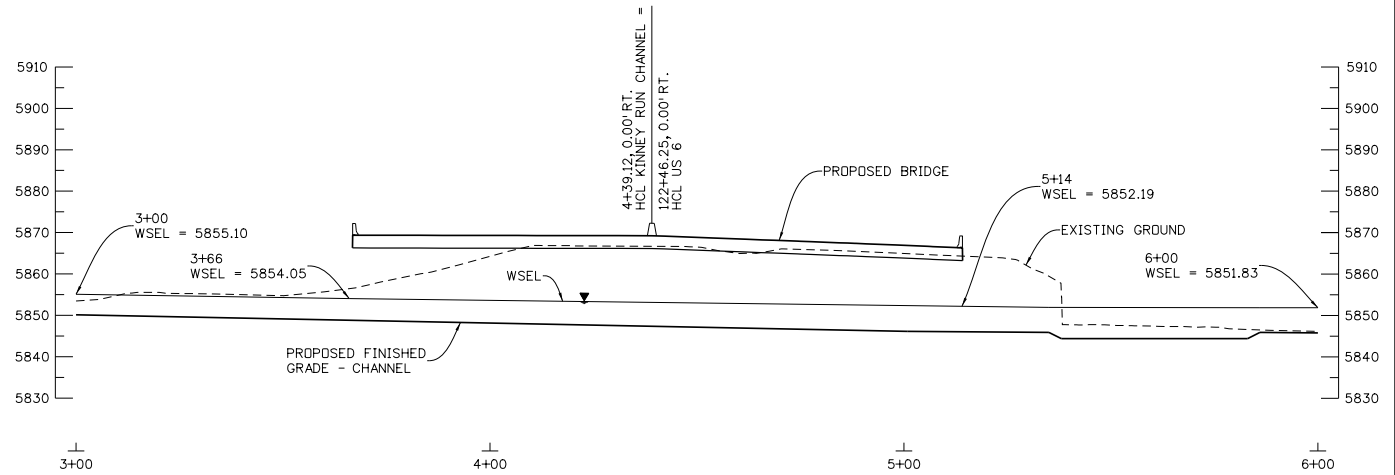
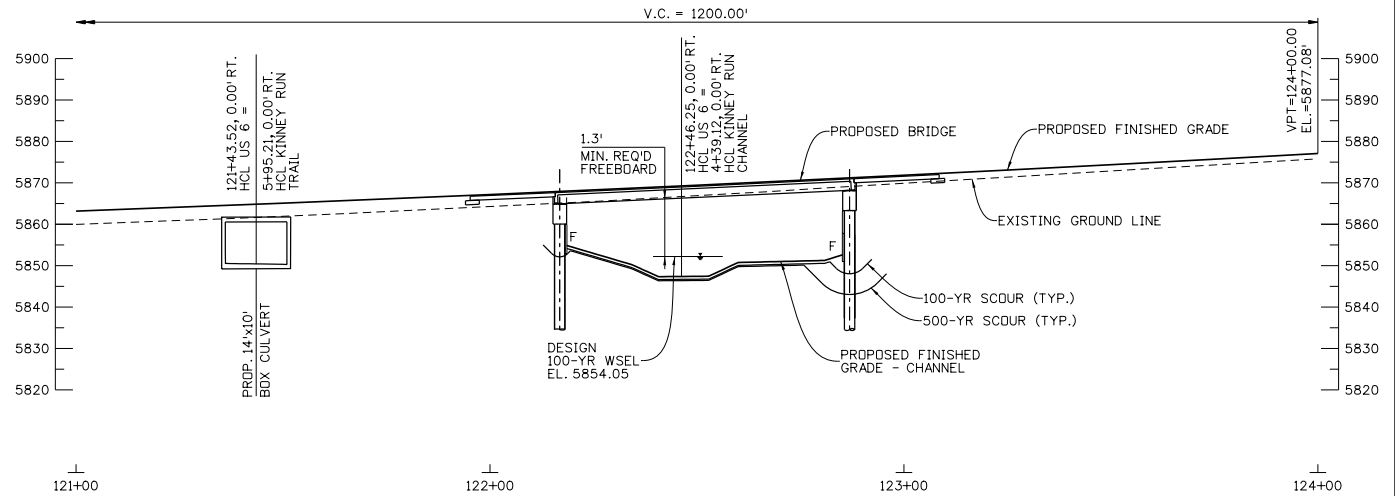
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 m:\cadd\p166\p166.dwg Date: 10/9/2020 10:00:00 AM Project: 22028BDDC.B07 Bridge Hydraulic Data 01



COMPARISON OF HYDRAULICS				
	VELOCITY (AVG) (FPS)	REQUIRED FREEBOARD (FT)	ACTUAL FREEBOARD (FT)	MAX. BACKWATER SURFACE ELEV. (FT)
EXISTING	2.7	0.9	0.1	5859.26
PROPOSED	7.4	1.3	9.9	5855.01

NOTE: CHANNEL IS BEING REALIGNED AND PROPOSED INVERT AT BRIDGE WILL BE 1-2 FEET LOWER THAN EXISTING

**CHANNEL DESCRIPTION**  
 EXISTING CHANNEL STREAM BED CONSISTS OF COHESIVE SOILS AND BOULDERS  
 STREAM FORM - MEANDERING  
 DEBRIS - LOW TO MODERATE DEBRIS STREAM  
 MANNINGS "N" FOR DESIGN: CHANNEL 0.045-0.065, BANKS 0.04  
 DRAINAGE AREA = 1.23 SQUARE MILES



Print Date: 10/9/2020	File Name: 22028BDDC.B07 Bridge Hydraulic Data 01
Horiz. Scale: 1:30	Vert. Scale: As Noted
<b>HR</b>	1670 BROADWAY, SUITE 3400 DENVER, COLORADO 80202 Phone: 303-764-1520 FAX: 303-860-7139

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Date:	Comments	Init.

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**Region 1**

As Constructed	No Revisions:
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Void:	

US 6 - WILDLIFE CROSSING BRIDGE HYRAULIC DATA (1 OF 2)	
Designer: J. MCANALLY	Structure Numbers: F-16-GA
Detailer: M. GRANT	
Sheet Subset: Bridge	Subset Sheets: B07 of 31

Project No./Code	TAP 006A-065
	22028
Sheet Number	50