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A Regional Ecosystem Framework for Terrestrial and Aquatic Wildlife along the I-70 Mountain Corridor, Colorado: An Eco-Logical Field Test

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ABSTRACT

Interstate 70 (I-70) is considered a major obstacle to wildlife movement in Colorado. The Colorado Department of Transportation (CDOT) has released the Final Programmatic Environmental Impact Statement, the first step in long-term planning for potential improvements to the I-70 Mountain Corridor (the Corridor) from Glenwood Springs to Denver. This planning process provides a unique opportunity to apply the Eco-Logical framework, an ecosystem based approach developed by the Federal Highway Administration to better integrate wildlife considerations and engage stakeholders in transportation planning. To accomplish this, Rocky Mountain Wild (formerly Center for Native Ecosystems) and ECO-resolutions, LLC collaborated with CDOT, Colorado Watershed Assembly and Western Transportation Institute to: 1) compile baseline information on the presence of, and use of existing crossing structures by, wildlife along I-70; 2) develop recommendations for mitigating the impacts of roads and traffic on wildlife, specifically road mortality and habitat fragmentation; and 3) facilitate the environmental review process and provide an enhanced forum for stakeholder involvement.

Original and existing information was collected relating to terrestrial and aquatic wildlife species. This information includes camera trap data on wildlife activity at existing bridges and culverts, wildlife habitat data from agencies, animal-vehicle collision data, and data obtained through a website where the public reported wildlife sightings. We then developed a transparent and repeatable process for identifying road sections that may require mitigation. This process was complemented by an extensive field survey that assessed the permeability of I-70 for select species. All information was analyzed and summarized to provide CDOT with recommendations for avoiding and minimizing impacts to terrestrial and aquatic wildlife during planning, design, construction, and operations and maintenance. In addition to site-specific recommendations, best management practices were formulated to provide general guidance for project-level planning throughout the Corridor. The recommendations were integrated into a web-based Context Sensitive Solutions Guidance Manual - a one-stop shop for project managers to identify potential conflicts with environmental and other community-valued resources.

To further support ecosystem-based planning, our team facilitated a sub-committee of agency and community stakeholders to create an Implementation Matrix to identify specific considerations for wildlife at each phase of potential infrastructure improvements. This process, based on the consensus of stakeholders, implements the goals of an interagency Memorandum of Understanding (signed by state and federal transportation, wildlife and land management agencies) to minimize impacts to wildlife.

These efforts are an excellent example of applying the Eco-Logical framework to a transportation corridor by creating a stakeholder process for incorporating ecosystem considerations. As a result, CDOT is now equipped with strategic guidance that can be used to avoid and minimize impacts to wildlife from the outset of project planning. The project will also facilitate environmental review processes by setting the stage for ongoing engagement with consulting agencies and public stakeholders and by providing clear measures and goals with which to design and evaluate transportation projects

in the Corridor. This foundation is tantamount to the successful integration of connectivity measures into transportation projects, and can be used as a model for transportation projects across the state as well as for other DOTs.

INTRODUCTION

The Interstate 70 (I-70) Mountain Corridor (the Corridor), between Glenwood Springs and Denver, presents one of the biggest obstacles to wildlife movement in the heart of the Rocky Mountains. Studies show that an average annual daily traffic (AADT) of 10,000 creates habitat avoidance or acts as a near complete barrier for all types of species (Charry and Jones 2009) although a number of species are susceptible to road mortality or barrier effects at lower traffic volumes. A highly-traveled interstate highway, I-70 AADT counts along this 130-mile stretch of interstate range from 15,300 at the western end of the segment to 67,200 at the eastern end (CDOT 2009). From 2000 to 2035, traffic counts in one location along this already congested highway are projected to jump 55 percent on the weekends and 85 percent during the week (CDOT and FHWA 2011, ES-4). Unless appropriate mitigation measures are instituted to provide wildlife passages, the barrier effect of this roadway will be complete.

According to the Draft I-70 Programmatic Environmental Impact Statement (PEIS) released in 2005, "the primary issue affecting wildlife in the Corridor is the interference of I-70 with wildlife movement and animal-vehicle collisions (AVCs). Barriers to wildlife movement include structural, operational, and behavioral impediments to wildlife trying to cross I-70" (CDOT and FHWA 2004, 3.2-5). In the 2011 Final PEIS, CDOT states further that "[e]ven where animals can cross the highway, traffic noise and vehicle lights can deter animals from approaching the highway and animal-vehicle collisions can result in their injury or death" (CDOT and FHWA 2011, 3.2-1).

Although transportation priorities are set well in advance of construction, many biologists, conservationists, and the public only comment at the Environmental Impact Statement stage in the process. At this point, it is often too late to avoid environmental impacts since most decisions are already in place. Conservation and community needs that are addressed late in the planning process can often slow down transportation projects and become unnecessarily costly. This can result in a strained relationship between the DOT and stakeholders, as well as a less than ideal highway design from an environmental, cultural, and social perspective.

Furthermore, because highway projects are typically designed and implemented on a project-by-project basis often without a landscape scale perspective, mitigation must occur within the project boundary as opposed to the location where it is most effective. For these reasons, the current transportation planning process does not always ensure that the right conservation mitigation happens in the right place.

As the state's population continues to grow, transportation infrastructure struggles to reduce congestion and accommodate expanding communities. I-70 in Colorado is a prime example: it is the only east-west interstate across Colorado and serves as a lifeblood of travel for Colorado and the nation, providing for the movement of people, goods, and services; it is a major corridor providing access to many of Colorado's recreation and tourism destinations; and it is an essential link in the national interstate highway system, the principal purposes of which are to connect major metropolitan areas and industrial centers by direct routes, and to provide a dependable, interconnected highway network to serve in national emergencies.

Existing congestion along I-70 is degrading the accessibility of mountain travel for Colorado residents, tourists, and businesses. Travel demand in the Corridor is projected to continue increasing over the next 25 years and beyond. The need to relieve this congestion is especially acute for weekend travelers seeking access between the Denver metropolitan area to the central mountains and Western Slope.

To relieve congestion along the I-70 Mountain Corridor, the Colorado Department of Transportation (CDOT) initiated a planning process for I-70 and released a Draft PEIS in 2005; however, the process was highly contentious, with disagreements on the preferred alternative, environmental and social impacts, and multimodal choices. A change in leadership at both the Governor and CDOT Director levels in 2007 brought new attention to the debate. CDOT recommitted the agency to better integration of stakeholder concerns into the discussion about the future of the interstate corridor and revisited the PEIS, releasing a Revised Draft PEIS in 2010. In June of 2011, the Federal Highway Administration (FHWA) signed the Record of Decision (ROD) for the Interstate 70 PEIS.

The I-70 Eco-logical Project was developed to field test the ecosystem approach developed by the FHWA (Brown 2006). The Regional Ecosystem Framework applies an ecosystem-based approach to developing transportation infrastructure by protecting and restoring aquatic and terrestrial connectivity while also improving predictability in environmental review. The progress that CDOT has made in the long-term planning for potential improvements along the I-70

Mountain Corridor offered a unique opportunity to apply the Eco-Logical framework and find ways to preserve and restore key wildlife linkages across Colorado's high country.

The ultimate objective of the project was to develop solutions for mitigating transportation impacts on wildlife habitat connectivity along the I-70 Mountain Corridor from Golden (MP 258, west of Denver) to west of Dotsero (MP 130). To accomplish this, Rocky Mountain Wild (formerly Center for Native Ecosystems) and ECO-resolutions, LLC collaborated with CDOT, Colorado Watershed Assembly (CWA) and Western Transportation Institute (WTI) to: 1) compile baseline information on the presence of, and use of existing crossing structures by, wildlife along I-70; 2) develop recommendations for mitigating the impacts of roads and traffic on wildlife, specifically road mortality and habitat fragmentation; and 3) facilitate the environmental review process and provide an enhanced forum for stakeholder involvement. These efforts are an excellent example of applying the Regional Ecosystem Framework to a transportation corridor by creating a stakeholder process for incorporating ecosystem considerations.

BACKGROUND

A Landscape Level Inventory of Valued Ecosystem Components (ALIVE)

In 2001, CDOT and FHWA convened an interagency group of wildlife specialists called A Landscape Level Inventory of Valued Ecosystem Components (ALIVE) to consider the negative impacts of existing and proposed transportation systems on wildlife habitat and movement patterns, and to guide mitigation development strategies as a part of the I-70 PEIS (CDOT and FHWA 2004). Other agencies engaged in the ALIVE committee include those responsible for the protection and management of wildlife habitats and threatened and endangered species – the Colorado Division of Wildlife (CDOW), the Bureau of Land Management (BLM), the US Forest Service (USFS), and the U.S. Fish and Wildlife Service (USFWS). The objective of this cooperative effort was to agree up-front to conservation strategies and mitigation measures to ensure timely environmental clearances for projects prioritized under the PEIS (Solomon 2007, 3).

The main goals of the ALIVE committee were fourfold:

- Designation of key wildlife habitat including Canada lynx habitat.
- Identification and characterization of linkage interference zones [or important wildlife movement areas].
- Analysis of specific conflict areas for wildlife roadway crossing within the linkage interference zones.
- Recommendations for mitigating conflicts through wildlife crossings and other techniques including fencing and land conservation strategies. (CDOT and FHWA 2004, 3.2-6)

Considering both existing data and expert opinion on wildlife movement, the ALIVE committee identified thirteen LIZs in the I-70 Mountain Corridor between Denver and Glenwood Springs. The ALIVE committee also proposed specific recommendations, including wildlife crossings and land protection, for each zone (CDOT and FHWA 2004). In 2008, at the outset of the I-70 Eco-Logical Project, the cooperating agencies and municipalities reconvened to sign a Memorandum of Understanding (MOU) to recommit to the collaborative effort for the Revised PEIS and leverage efforts on future projects in the I-70 Mountain Corridor on behalf of terrestrial and aquatic resources (CDOT and FHWA 2011, ES-7).

Stream and Wetland Ecological Enhancement Program (SWEEP)

The CDOT convened Stream and Wetland Ecological Enhancement Program (SWEEP) committee, initiated through the I-70 PEIS process, is an inventory of water resource-related issues in the Corridor. SWEEP includes representatives from several federal, state and local government agencies, including USFWS, USFS, BLM, CDOW and Clear Creek County; various watershed associations including Clear Creek Watershed Foundation, Upper Clear Creek Watershed Association and Eagle River Watershed Council; and special interest groups such as Colorado Trout Unlimited. A MOU was signed between these groups in 2011 to coordinate and leverage efforts on future projects in the I-70 Mountain Corridor on behalf of aquatic resources. Though SWEEP focuses on a variety of issues regarding stream and wetland health, coordination between the ALIVE and SWEEP groups will ensure consideration of aquatic connectivity throughout the Corridor (CDOT and FHWA 2011).

Context Sensitive Solutions (CSS)

The I-70 Mountain Corridor Context Sensitive Solutions (CSS) process was developed by CDOT and I-70 Mountain Corridor Stakeholders "to consider the total context of a proposed action—not just the study's physical boundaries" (Peter Kozinski, CDOT, pers. comm., June 23, 2011). The CSS process is intended to guide all future and/or Tier 2 processes in the I-70 Mountain Corridor, incorporating the goals of many of the I-70 Mountain Corridor Core Values – such as sustainability, biological resources, and communities – at each stage. The web-based CSS Guidance will

provide Tier 2 project leaders and teams with the pertinent information and data available for the variety of issues, including habitat connectivity, which may occur at each future project location (CDOT and FHWA 2011).

METHODS AND RESULTS

A major outcome of the I-70 Eco-Logical Project are site-specific recommendations and general guidance for improving terrestrial and aquatic connectivity along the I-70 Mountain Corridor. An extensive field survey was conducted to assess the current permeability of I-70 for select species, and served as the foundation for developing mitigation recommendations for improving existing structures or constructing new structures to provide safe passage. In addition, original and existing information was compiled on terrestrial and aquatic wildlife; this information derived from a variety of sources including camera trap data on wildlife activity at existing bridges and culverts, wildlife habitat and species presence data from agencies, animal-vehicle collision data, and data obtained through a website where the public reported wildlife sightings. This compilation of data and information was then used to develop a transparent and repeatable process for updating and validating the 13 LIZs identified in 2003 and develop an analogous process for identifying road-stream crossings that are important for aquatic connectivity. All of this information was analyzed and summarized to provide CDOT with recommendations for avoiding and minimizing impacts to terrestrial and aquatic wildlife during each of the life cycle stages of future transportation projects.

Data Compilation

Inventory of Potential Wildlife Passages and Barriers to Movement

The purpose of the roadway inventory was to characterize the stretch of interstate between MP 130 (west of Dotsero) and MP 258 (Golden) with regards to habitat connectivity for wildlife (Figure 1). This stretch of interstate crosses multiple ecological zones and extends from an elevation of 5,700' west of Golden to over 11,000' at the Eisenhower Tunnel, and back down to 6,100' at Dotsero.

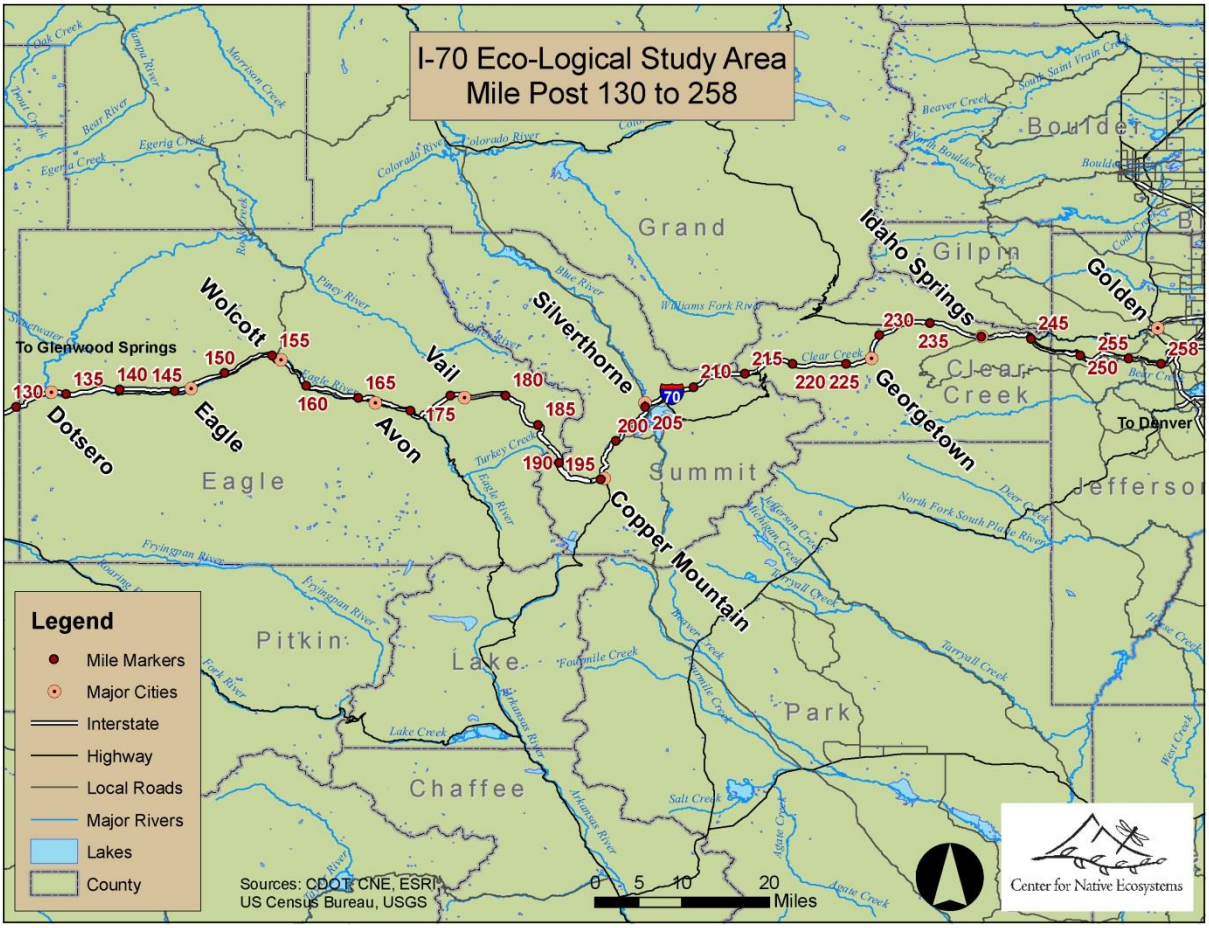

Figure 1. I-70 Eco-Logical Study Area, Mile Post 130 to 258.

Within the study area, every structure greater than one meter in diameter, including pipes, bridges and culverts, was inventoried and characterized according to its potential to function as a wildlife passage. Other locations without an existing structure, such as fill slopes, where wildlife are barred from crossing the roadway or attempt to cross at grade were also inventoried. At each location, site-specific data were compiled to characterize habitat connectivity across the roadway for terrestrial and, if applicable, aquatic wildlife. The inventory included structure dimensions and characteristics, habitat information, fencing and other barriers to movement. Sites identified as having an aquatic component were further assessed based on a number of additional criteria designed to evaluate connectivity for aquatic species.

In addition to the roadway inventory, a GPS unit was used to map stretches of roadway with wildlife fencing, including gaps in the fencing (for example at highway interchanges). Locations that tie into an existing structure (i.e. bridge or culvert) with no resulting gap were not mapped; nor were locations where the fencing connects into a natural barrier, such as a cliff wall, and starts up again a few tenths of a mile up the road. One-way deer gates and escape ramps have also not been mapped. Other barriers to wildlife movement within 100 meters of the roadway – such as steep cliff bands and retaining walls – were included in the inventory.

Camera Monitoring

Camera monitoring was conducted to collect baseline information on the presence and use of existing crossing structures by wildlife along I-70. In 2009, cameras were set up at 29 monitoring stations at 15 milepost locations. Over the course of the 2009 field season, this was increased to 34 stations at 19 milepost locations. In the 2010 field season, cameras were set up at 39 monitoring stations at 24 milepost locations, targeting sites preliminarily identified as important for wildlife movement. Monitoring locations included existing bridges and culverts as well as potential crossing locations – such as fill slopes blocking natural drainages – where there are no suitable crossing structures.

Monitoring activities in 2010 were focused within areas of identified connectivity concern as determined by a preliminary analysis used to validate and refine previously-identified LIZs first mapped in 2004 by the ALIVE group. Recognizing that camera monitoring does not fully capture all wildlife activity at a site (Bonaker 2008), in 2010 an attempt was made to expand monitoring to include track beds using the existing substrate at the site. However, due to insufficient substrate that did not register track imprints well, the track beds were discontinued for the purposes of this study, as they were contributing little additional data at a high cost of staff time and travel. Anecdotal data from the track beds was collected when researchers were in the field to maintain the cameras every four to six weeks. No monitoring was conducted to track measures of aquatic connectivity as a part of this study.

Camera monitoring captured activity by a variety of species across the study area. The most frequently photographed species was mule deer. Elk, red fox, black bear, rabbit/hare, raccoon and coyote were also commonly caught. Other species captured by the cameras include marmot, badger, striped skunk, squirrel, moose, gray fox, porcupine, bighorn sheep, weasel, wood rat, red-tailed hawk, bobcat and mountain lion, as well as domestic animals such as goats, cattle, dogs and house cats. Human use at monitoring stations varied from none to frequent, depending on the location. Some level of human activity was documented at nearly all of the culvert and bridge locations, while little to no use was documented at monitoring locations without structures. Very little wildlife activity was recorded at structures that received regular movement of passenger cars and trucks through the structures. One camera was stolen in 2009, three in 2010.

Terrestrial Habitat Data

Wildlife habitat data were compiled for each terrestrial target species within the I-70 Mountain Corridor for which spatial data was available. Target species included any species with threatened and endangered, sensitive, and other special status, or any other species with a safety or habitat fragmentation concern in the context of the I-70 Mountain Corridor. Data used in this analysis includes data from various sources for AVCs and habitat layers for bighorn sheep, black bear, boreal toad, elk, lynx, moose, mountain lion, mule deer, northern leopard frog, Preble's meadow jumping mouse and river otter, which were derived from CDOW's Natural Diversity Information Source database and other sources.

Aquatic Species Presence and Habitat Data

The aquatic target species included any threatened and endangered, sensitive, and other special status native species found in the Corridor as well as any native species presenting a barrier or habitat fragmentation concern in the context of the I-70 Mountain Corridor. The aquatic target species were vetted with aquatic biologists at CDOW and USFWS.

CDOW is the authoritative source for all aquatic data in the state of Colorado (Harry Vermillion, CDOW, pers. comm., March 10, 2011). Therefore data was requested from the agency to determine whether the presence of target species

were confirmed, absent or unknown (some structures had no available data) at each inventoried location with perennial flow. At some locations, natural or man-made barriers are desirable in order to protect existing native cutthroat trout populations from invasion by non-natives, allow for the potential to reclaim habitat for native cutthroat trout populations and/or protect current fish populations from whirling disease. Information on intentional barriers throughout the study area was obtained through communications with the individual aquatic biologists at CDOW whose assigned districts fall within the Corridor. Due to the potential to restore native cutthroat trout to some stream segments, some locations were identified as potential barrier locations even though there is currently no barrier present.

I-70 Wildlife Watch

I-70 Wildlife Watch is a web-based wildlife observation data collection tool that allows motorists to report wildlife, both alive and dead, that they see along I-70 between Golden and Glenwood Springs. The website was developed by WTI at Montana State University (MSU) for the I-70 Eco-Logical Project and was modeled after similar websites in British Columbia, Canada, Ketchum, Idaho and Bozeman Pass, Montana. This on-line database works both to educate drivers about wildlife crossing issues along I-70 as well as compile opportunistic information on wildlife activity along the highway that cannot otherwise be determined from road-kill counts or accident reports.

A number of complementary strategies have been implemented to teach the public about I-70 Wildlife Watch and encourage them to participate, beginning with a press event at the Colorado Division of Wildlife headquarters in Denver, Colorado on November 9, 2009. The website launch was conducted in coordination with the *Colorado Wildlife on the Move* coalition which is composed of Rocky Mountain Wild, ECO-Resolutions, LLC, CDOT, Colorado State Highway Patrol (CSP), CDOW and Rocky Mountain Insurance Information Association. Additional outreach efforts consisted of a billboard deployed at two strategic times during the study period with associated press releases, handouts such as flyers and business cards, and a Friends of I-70 Wildlife Watch concept aimed at getting other businesses and organizations to promote use of the website through various means. For instance, Denver Zoo has a link to I-70 Wildlife Watch on their conservation webpage and has promoted the website at a variety of events.

Motorists were asked to participate in I-70 Wildlife Watch by reporting wildlife observations, dead or alive, over a distance of about 145 miles - between exit 114 (West Glenwood Springs) and exit 259 (US40 - Red Rocks/Golden/Morrison). Users were required to answer several questions about their observation including: was/were the animal(s) road-killed or alive, the location of the animal(s) in relation to the roadway, species, number of individuals sighted, date and hour of the day of the sighting, which exits the driver entered and exited the roadway on the trip when the sighting was made, and how many times the observer has driven the same section of highway prior to the observation date without making an observation.

Between November 9, 2009 and April 19, 2011, users submitted 330 unique wildlife reports of live animals. Some sightings were of more than one live animal; therefore, the total unique animal count for all species was much higher at 1227 animals. The largest proportion of live observations was attributed to bighorn sheep followed by mule deer and elk. Users also submitted 100 unique reports of dead animals. The largest proportion of carcass observations was attributed to mule deer followed by unknown and red fox.

By requiring users to note where they entered and exited the highway when a sighting was made, a general sense of reporting effort can be assessed, such that patterns of observations can be discerned while controlling for the number of times that a given segment has been travelled. In general, correcting for observers seemed to accentuate the number of sightings in the western portion of the study area while it minimized the number of sightings in the east. This is due to the fact that there were fewer drivers participating in the website in the west compared to those participating in the east. Comparing the exit data to the AADT also began to tell us where people are participating and where additional outreach is needed. The largest percentage of the AADT participating in the website occurred on West Vail Pass and the smallest between the two exits for Glenwood Springs.

Observations collected by the public on I-70 Wildlife Watch complements other data on wildlife habitat and activity adjacent to the roadway. Before the website was instituted, much of the knowledge about wildlife activity near the roadway was based solely on AVC data collected by CSP and CDOT. These data consist mostly of collisions that were serious enough to report; therefore, AVCs are generally recognized as being severely underreported as well as unevenly reported over time and geographies. Romin and Bissonette (1996) recommend factoring in a 16-50 percent reporting rate when estimating AVC levels from accident reports. The sightings reported by motorists in the I-70 Mountain Corridor greatly expanded our knowledge of where live animals are most frequently seen along the roadway as well as about otherwise under- or unreported road-killed animals (i.e. smaller animals such as red fox and raccoon).

Data Analysis and Recommendations Development

Terrestrial Connectivity Locations - Linkage Interference Zones - 2011

The ALIVE committee used expert opinion to assess the best available data at the time to identify the 2004 LIZs, however the decision-making process was not rigorously systematic or repeatable, preventing future revisions using the same methodology. The I-70 Eco-Logical Project therefore developed a new approach for validating and refining the 2004 LIZs with the objective of creating a consistent and transparent process for reassessing terrestrial connectivity zones along the I-70 Mountain Corridor. These refined zones, by agreement of the ALIVE committee, are called Linkage Interference Zones-2011 (LIZs-2011), to distinguish them from the LIZs identified in the original assessment in 2004.

The primary steps for this GIS supported analysis included identifying primary and secondary parameters for prioritizing road segments based on their potential contribution to habitat connectivity for wildlife; ranking and tallying the presence/absence of these primary parameters for each 1/10th mile segment along the Corridor; and applying decision rules for delineating discrete connectivity zones within each bioregion and applying the secondary criteria as appropriate. An objective for the analysis was to identify at least one LIZ-2011 within each bioregion of the study area.

The primary parameters mentioned in the data compilation section above (i.e., target species or AVC data), were ranked on a standardized scale so that all values at a given location could be summed. Each parameter was given a maximum score to avoid one parameter having an unreasonable weight within an analysis segment. This also helped maintain a balance between parameters that have more or less sub-parameters, or available habitat and movement data layers. Federal and state threatened and endangered species were given a higher maximum possible score than the more common game species.

Available data layers for a given focal species were included in the analysis only if the habitat was identified as important habitat (e.g., winter range, movement corridor) for that species. In general, CDOW rankings (2008) for priority wildlife habitat for economic species and species at risk were used as a guideline for prioritizing and scoring sub-parameters. In determining scores for each sub-parameter, species identified as 'sensitive' (e.g., boreal toad and Canada lynx) and more sensitive habitat types (e.g. boreal toad breeding sites) were given a higher individual score than more general habitat types (e.g. overall range), unless the CDOW rankings (2008) used for guidance dictated otherwise.

In the GIS, these habitat values were related to a buffered layer of I-70 reflecting the boundaries of our study area, divided into 1/10th mile segments. Total scores were calculated for each 1/10th mile segment and smoothed with the adjacent scores to acknowledge that one segment is likely influenced by its two neighboring segments (Huijser et al. 2008, 21). Based on the smoothed scores, the 20th, 40th, 60th, 80th and 100th percentiles were calculated. A series of decision rules and secondary criteria were applied to the ranked 1/10th mile segments to delineate the final LIZ-2011s. This analysis process and results went through a thorough review process by the ALIVE committee, including several in-person meetings, to ensure acceptance of this dataset by the stakeholder groups and its inclusion in decision-making about the Corridor, specifically, to inform mitigation measures for wildlife connectivity.

Seventeen distinct connectivity zones, representing five of the six bioregions in the I-70 Mountain Corridor, were identified (Figure 2). The alpine bioregion, the only one not represented in the LIZ-2011s, is very short and has an existing land bridge over the interstate for most of its entirety where the Eisenhower/Johnson Tunnels cross under the Continental Divide. The primary parameters exerting the greatest influence on how each LIZ-2011 was defined and mapped include elk, mule deer, lynx and animal-vehicle collisions.

A comparison of the 2011 and 2004 LIZs shows some locations identified in both analyses as well as several that were only identified in one or the other. Seventeen LIZs, covering approximately 51 miles, were identified in the 2011 analysis, compared to 13 zones encompassing 65 miles in 2004. The 2004 analysis also includes two LIZs for which sub-segments were identified. While both analyses incorporated many of the same types of data layers, the LIZ-2004 process was based on expert opinion assessing the available data layers. In addition, the specifics of the LIZ-2004 analysis process are not well documented, and so the process is not replicable with more up-to-date datasets.

Mitigation recommendations and guidelines for improving permeability for terrestrial wildlife were developed for each of the revised LIZ-2011s. Data from the camera monitoring and I-70 Wildlife Watch were used to further refine the recommendations by providing pertinent information at specific locations along the Corridor. Through the ALIVE MOU, CDOT and other participating agencies have committed to using updated data such as these during Tier 2 processes, which guide planning and design for specific infrastructure projects in the I-70 Mountain Corridor (ALIVE MOU 2008).

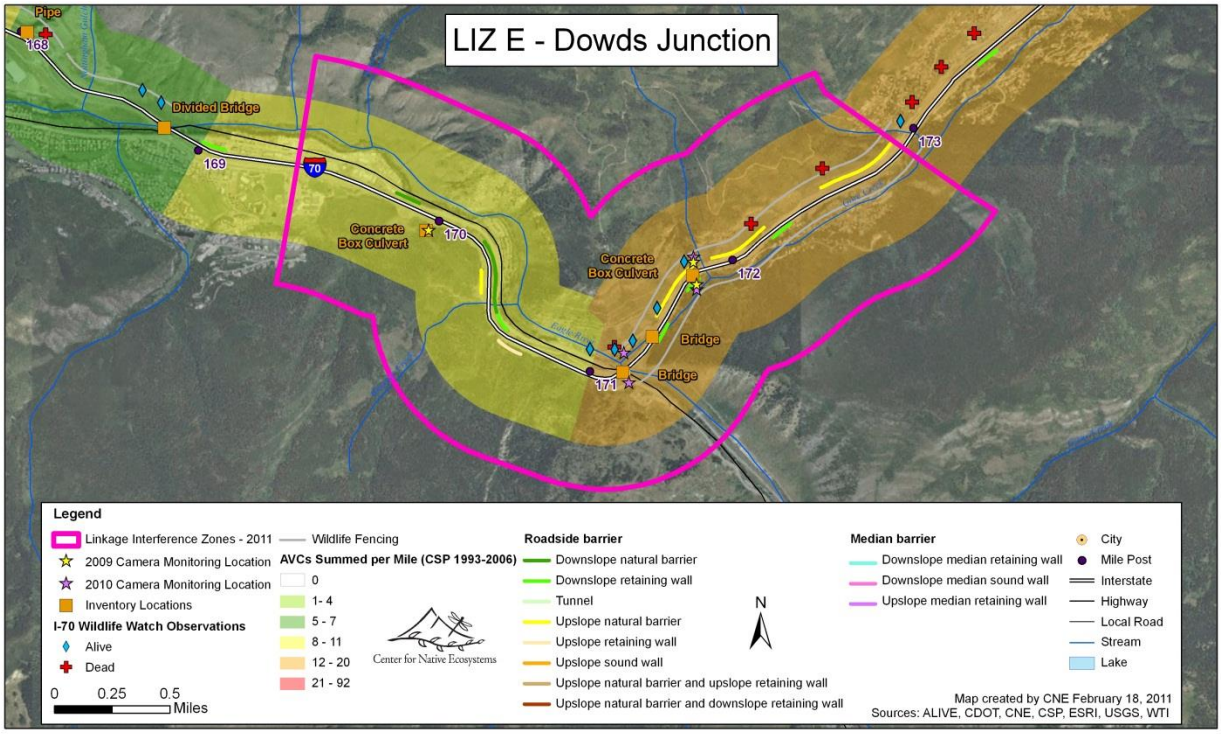

Figure 2. LIZ E – Dowds Junction – Map shows the boundary of a LIZ resulting from the 2011 analysis and associated compiled data including inventory locations, mapped wildlife fencing and other barriers, camera monitoring stations, I-70 Wildlife Watch observations, and AVC data.

Aquatic Connectivity Locations

In order to make site-specific recommendations at aquatic structures within the study area, we assessed each inventoried location with perennial flow to determine whether or not it presents an aquatic connectivity concern. The two main criteria used to decide whether a location is a priority for aquatic connectivity were: 1) presence of a target species and 2) absence of intentional barriers along the stream segment.

Site specific recommendations were developed for locations determined to be a priority for aquatic connectivity because of the presence of a target species and the absence of intentional barriers. Site-specific recommendations were also made for locations with unknown connectivity priorities, or sites where the presence of a target species is unknown but no intentional barriers exist. This process was vetted with both the ALIVE and SWEEP committees.
General Terrestrial and Aquatic Guidance

In addition to site-specific recommendations, a comprehensive suite of guidelines for improving permeability for terrestrial and aquatic wildlife was developed to inform projects throughout the Corridor, regardless of whether or not they fall within an identified LIZ. This guidance was compiled from a synthesis of best management practices in use by state and federal agencies and recommended by research studies across the nation, and was reviewed by road ecology colleagues in several states. The guidance includes practices for siting and designing pipes, culverts and bridges to facilitate wildlife passage.

Stakeholder Processes

ALIVE, SWEEP and CSS Processes

The I-70 Eco-Logical Project team members have worked closely within the framework of the previously established stakeholder groups in the I-70 Mountain Corridor to communicate with and engage stakeholders in the project. Such stakeholder involvement is essential for building support among communities, partner agencies and other interest groups as transportation projects proceed through visioning, planning, design and construction. Early engagement ensures that stakeholder concerns are duly considered and incorporated into the transportation planning process and improves predictability in the environmental review process.

The project team collaborated with the ALIVE and SWEEP committees to ensure that stakeholders played a major role in defining the objectives of the project, reviewing the processes for evaluating connectivity concerns and needs, and critiquing project outcomes. This consisted of regular in-person meetings throughout the life of the project to update stakeholders on the status of the project and gain valuable feedback which was incorporated in subsequent steps. Before the I-70 Eco-Logical Project terminated, both the ALIVE and SWEEP committees agreed to hold annual meetings to address upcoming projects, thereby ensuring that stakeholder engagement continues beyond the life of the project. CDOT has further committed to providing quarterly updates to members of both committees regarding future projects big and small to ensure that stakeholder participation continues in the future.

All data and recommendations resulting from the I-70 Eco-Logical Project have been integrated into the web-based CSS Guidance Manual which is a one-stop shop for project managers to acquire data on environmental and other community-valued resources and to identify potential conflicts at the outset of transportation planning processes. The CSS Guidance Manual includes standard design solutions, historic context, and decision making procedures to be used at each life stage of project development along the Corridor. Incorporating connectivity into the CSS process ensures that the products from the I-70 Eco-Logical Project will be applied as projects move from one life stage to the next in the I-70 Mountain Corridor.

ALIVE Implementation Matrix

To further support ecosystem-based planning and coordination among agencies and stakeholders, the project team facilitated a sub-committee of agency and community stakeholders to create an Implementation Matrix to identify specific considerations for wildlife at each phase of potential infrastructure improvements. This process, based on the consensus of stakeholders, strengthens the ALIVE process by implementing the goals of the MOU to minimize impacts to wildlife throughout the I-70 Mountain Corridor. The process was modeled after a similar matrix developed by the SWEEP committee to carry out the goals of their MOU.

The ALIVE Implementation Matrix was developed by a working group that included members from CDOT, CDOW, USFS, USFWS, ECO-resolutions, LLC, Rocky Mountain Wild and Clear Creek County. After completing a draft with the working group, the Matrix was reviewed by the full ALIVE committee before the final was submitted to CDOT.

The ALIVE Implementation Matrix outlines specific inputs (e.g., wildlife and land use data), considerations (e.g., what opportunities exist to improve, protect or restore permeability and habitat components?), and outcomes (e.g., avoidance and mitigation strategies) necessary for consideration at each of the five life cycle phases for improvements in the I-70 Mountain Corridor that are needed to improve, protect, or restore permeability for wildlife and important habitat components, as put forth in the ALIVE MOU. The five life cycle phases include 1) corridor planning, 2) project development, 3) project design, 4) project construction, and 5) operations, maintenance and monitoring. As activities in the Corridor move from corridor planning to project development to project design and so on, the outcomes from the previous phase become inputs for the subsequent phase. This approach is consistent with the Life Cycle Phases and 6-Step Process in the CSS Guidance for the I-70 Mountain Corridor (CDOT 2010).

This matrix further applies the Eco-Logical framework by implementing the main objective of the ALIVE MOU which is to "increase the permeability of the I-70 Corridor to terrestrial and aquatic species….This includes development of management strategies that will result in the long-term protection and restoration of wildlife linkage areas that intersect the I-70 Corridor, improve habitat connectivity, and preserve essential ecosystem components" (ALIVE MOU 2008).

DISCUSSION AND CONCLUSION

The recent progress that CDOT has made in the long-term planning for the I-70 Mountain Corridor has presented a unique opportunity to field test the Regional Ecosystem Framework developed by FHWA in 2006. As a result of this project, CDOT is now equipped with a comprehensive assessment of permeability for wildlife throughout the I-70 Mountain Corridor as well as the tools for integrating corrective actions in future projects to improve habitat connectivity for wildlife. The establishment of a framework for integrating connectivity data and concerns as well as stakeholder review will bring both immediate and long-term benefits, helping to streamline projects and produce sustainable projects that meet ecological, community, and transportation goals.

In addition to supporting stakeholder engagement, the I-70 Eco-Logical Project resulted in the compilation of a comprehensive dataset about the state of habitat connectivity for wildlife in the Corridor, and provided detailed recommendations for improving connectivity. The seventeen identified LIZs-2011 and aquatic connectivity locations reflect our best understanding of wildlife movement needs across the interstate, and these can be easily updated as new data becomes available, for example, for species for which spatial datasets are currently lacking. While compiling

data and producing new data can be a time-consuming endeavor, such data collection efforts form the backbone of support for decision-making; by having these data on-hand, the agency no longer needs to choose between postponing project-level decisions for lack of data or making decisions based on a paucity of data.

As the I-70 wildlife data and recommendations are now integrated into the CSS website, project managers see connectivity concerns flagged each time a new project overlaps an identified LIZ, facilitating considerations of these concerns from the earliest stages of project visioning and planning. The recommendations provided offer initial guidance for restoring permeability for wildlife across the interstate. As engineering solutions expand and research helps us learn what works and what doesn't work for different species, these preliminary recommendations can be tailored or even revised to provide the best connectivity solution at a given location.

While the CSS database and the Eco-Logical database were prepared specifically for the I-70 Mountain Corridor, they may be expanded to cover the entire state to support planning efforts across Colorado. While the stakeholder groups were convened prior to the I-70 Eco-Logical Project, they lacked a clear system for how and when to engage, such that neither CDOT nor the stakeholders themselves knew how to effectively engage. Through this field test, a clear framework has been developed for ensuring that stakeholder concerns and information are integrated at each life cycle phase in the planning process.

The I-70 Eco-Logical field test has demonstrated the value of well-defined stakeholder engagement procedures and up-front data compilation efforts to support transportation planning that considers the full landscape context – both ecological and human. By making this information fully accessible to project engineers as well as interested partners outside of CDOT, the responsibility for ecological-based decision-making extends beyond agency biologists and provides a foundation for integrative projects and sustainable transportation infrastructure.

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BIOGRAPHICAL SKETCHES

Paige Singer was the project coordinator and GIS specialist for the I-70 Eco-Logical Project. She has been a staff biologist/GIS specialist for Rocky Mountain Wild (formerly Center for Native Ecosystems) since 2008. She has a B.A. in Psychology from Stanford University, and an M.S. in Environmental Studies from the University of Montana. Paige has studied human-wildlife interaction issues in areas as diverse as Montana and Africa. Before coming to RMW, Paige coordinated the Citizen Science Wildlife Monitoring Program with the Southern Rockies Ecosystem Project.

Julia Kintsch was the project director for the I-70 Eco-Logical Project. She is a conservation ecologist and the founder of ECO-resolutions, LLC ecological resources consulting, where she conducts wildlife and habitat assessments, develops road-wildlife mitigation recommendations, and facilitates conservation management for public, private and non-profit clients. Julia holds a Master's Degree in conservation biology from Duke University and has extensive experience in conservation planning, ecological resource management, and mitigating impacts from infrastructure and human activities on wildlife. Previous roles include conservation scientist at Freedom to Roam, director of programs at the Southern Rockies Ecosystem Project, and conservation planner at the Nature Conservancy.

Marcel P. Huijser was the terrestrial principle investigator for the I-70 Eco-Logical Project. He received his M.S. in population ecology (1992) and his Ph.D. in road ecology (2000) at Wageningen University in Wageningen, The Netherlands. He studied plant-herbivore interactions in wetlands for the Dutch Ministry of Transport, Public Works and Water Management (1992-1995), hedgehog traffic victims and mitigation strategies in an anthropogenic landscape for the Dutch Society for the Study and Conservation of Mammals (1995-1999), and multifunctional land use issues on agricultural lands for the Research Institute for Animal Husbandry at Wageningen University and Research Centre (1999-2002). Currently Marcel works on wildlife-transportation issues for the Western Transportation Institute at Montana State University (2002-present) and he is a member of the Transportation Research Board (TRB) Committee on Ecology and Transportation.

Alison Huyett was the project assistant for the I-70 Eco-Logical Project. She was the Assistant Staff Biologist at Rocky Mountain Wild (formerly Center for Native Ecosystems) from 2009 to 2011. Her main roles for the I-70 Eco-Logical Project were field data collection, data management and analysis, and assisting with various reports. During her time at

RMW, she ran several of the citizen science projects, assisted in fund-raising opportunities and membership management, as well as, contributing to other RMW campaigns. Alison received her B.S. in Wildlife Conservation and Entomology from the University of Delaware and is now a Master's candidate in the Environmental Management program at Duke University.

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