

**California Highway 89 Wildlife Crossing Structures: Planning, Construction, and  
Effectiveness**

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Geography

by

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San Francisco, California

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## Certification of Approval

I certify that I have read “California Highway 89 Wildlife Crossing Structures: Planning, Construction, and Effectiveness” by Maret I. Bartlett, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirement for the degree Master of Arts in Geography at San Francisco State University.

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# **California Highway 89 Wildlife Crossing Structures: Planning, Construction and Effectiveness**

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San Francisco, California  
2022

This thesis evaluates the planning, construction and follow-up monitoring of three wildlife crossing structures at Kyburz Flat and at Sagehen Pass - on Highway 89 in Sierra County, CA. The project was initiated by the Highway 89 Stewardship Team (H89ST), which included federal, state, and local government, academic, and non-profit organizations. The evaluation includes three methods of analysis: archival research, semi-structured interviews, and analysis of animal carcass data and camera trap data collected by team members. The evaluation is made within the framework of “adaptive co-management”, which advocates the involvement of multiple individuals and organizations that are affected by, and bring resources to complex environmental issues, and for an iterative process of monitoring, evaluation, and adaptive solutions for such problems. The interviews mostly confirmed the archival research, finding that the H89ST was a collaborative process, and was successful in that regard. However, while monitoring of structure use was undertaken, goals of experimentation with the structures were not realized. The data analysis shows that wildlife-vehicle collisions have dropped by 83 – 94% since the structures were built, however, collisions have also declined all along the highway, leading to questions regarding the area deer herd’s status. Camera trap data indicates that the structures are being used, with estimated “passage rates” of 53-62% at the Sagehen structures, and ~65% at the Kyburz structure.

## **Preface and/or Acknowledgements**

Many thanks to all the members of the Highway 89 Stewardship Team who so generously gave of their time and assistance for the research of this thesis. Also thank you to my thesis advisors, Professors Nancy Wilkinson and Jerry Davis for their great advice and support, to my husband and son for their patience and support, and to the people of the northern Sierra Nevada for their work towards a peaceful and prosperous co-existence with nature.

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## Introduction

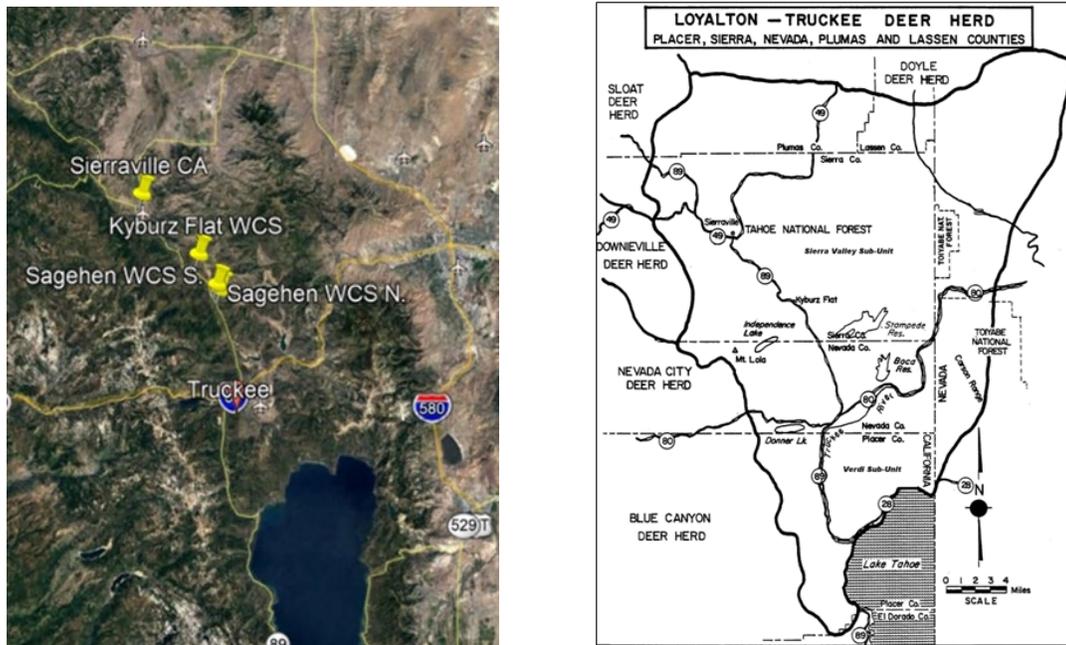
High quality wildlife habitat is shrinking on our planet, resulting in the decline of many species. While several factors including climate change, pollution, and urban development are core contributors to this problem, isolation of wildland habitat and the loss of habitat connectivity due to transportation corridors is also a major contributor to the decline of terrestrial species. Highways and other transportation corridors regularly bisect both urban and rural landscapes, resulting in wildlife-vehicle collisions and presenting barriers to wildlife seeking access to food, water, shelter, and mates. In addition, wildlife collisions present a significant problem for drivers on these roadways.

An important solution that has emerged to address wildlife habitat connectivity in recent decades is wildlife crossing structures (WCS). Because they require expertise in infrastructure engineering and wildlife biology, funding, and coordination among various government jurisdictions, and affect property owners on either side of the roadway, WCS benefit from the cooperation of multiple governmental, non-governmental organizations (NGO's), and individuals for their design and placement, funding, and political support. In addition, because these structures are still relatively rare and their use by wildlife can vary among species, experts in this field recommend that they be monitored for several years to assist in improving the design and placement of future WCS. The involvement of multiple decision-makers at different scales and the monitoring function recommended for these structures calls up an area of best practice that can be used with respect to WCS, which is adaptive co-management.

In the northern Sierra Nevada, along California Highway 89 in rural Sierra County, three wildlife crossing structures were built between 2008 and 2016, although the planning process for these structures was initiated much earlier, in 2002. As of 2019, Sierra County had a population of 3,005 - the second lowest of all counties in the State of California (US Census Bureau, 2021). The County is 962 square miles in size, and the Tahoe National Forest occupies the majority of it (Wikipedia, Sierra County CA, 2021). According to the County's General Plan, forest land covers 91% of the County area, with agriculture land covering another 7% (Sierra County General Plan, 2012). Sierra Pacific Industries has logging interests in the National Forest lands, and recreation-oriented businesses and ranching are also major economic drivers in the County.

Mule deer (*Odocoileus hemionus*) are considered a valuable game animal in this region, both by local and visiting hunters. The range of the Loyalton-Truckee mule-deer herd is shown below in Figure 1, and the location and photos of the wildlife crossing structures are shown in Figure 2. The herd migrates between the Sierra in the summer, and the eastern Sierra Valley and the State of Nevada in the winter. The Little Truckee River crosses Highway 89 north of the Sagehen WCS locations, and along with other creeks and the Truckee River further south it forms part of the migration corridor for the deer.

**Figure 1. Loyalton-Truckee Deer Herd Range and Location of Hwy 89 Wildlife Crossing Structures**



*Figure 1. Left, Source: Goodleeearth.com. Right, Source: Loyalton-Truckee Deer, 2022.*

The deer herd is considered “stable-to-declining” with an estimated size of ~3,200 individuals. (Loyalton-Truckee Deer, 2022). “In 1982, when the California Department of Fish & Game wrote its last herd management plan, the population was about 7,000 animals. Using similar but more advanced population estimates we calculate that we have around 3,000 now...” (Wong, 2010). Some of that loss is directly attributable to wildlife-vehicle collisions. Caltrans collected wildlife-vehicle collision data on Highway 89 in Sierra County for over 27 years, and during that time over 900 animals were killed – most of them deer.

**Figure 2. Sagehen and Kyburz Flat Wildlife Crossing Structures**



*Figure 2. Top left: Sagehen North Wildlife Crossing Structure, Top Right and Bottom: Kyburz Flat Wildlife Crossing Structure. Photos by author..*

While most of the recorded wildlife-vehicle collisions are with deer, other large animals including bears, coyotes and mountain lions are affected by roadways, as are smaller animals seldom counted in accident statistics. In the Sierra Nevada, smaller mammals such as the Sierra Nevada red fox, and the North American wolverine are listed as endangered or threatened species (Endangered and Threatened, 2022), while other animals such as the American marten are species of concern.

The process by which the three structures came to be built involved the formation of an inter-agency group called the Highway 89 Stewardship Team (H89ST), which included federal,

state, and local government representatives as well as academic and non-profit organizations. As such, the H89ST may be considered as an early example of the collaborative, or adaptive co-management model as applied to conservation issues. However, the process of completing the Highway 89 structures was not without challenges. In particular, the team did not complete an evaluation of the crossing structures' effectiveness based on wildlife use and wildlife-vehicle collision data.

This thesis explores the formation of the H89ST and evaluates the planning, funding, design, and monitoring process for the original Highway 89 wildlife crossing structures. It addresses the motivations of the team, the resources its members and organizations brought to the endeavor, and how the crossing structure projects fit within the members' missions and goals. What was learned from this process and how can it be improved for such projects in the future? It is hoped that this study will contribute to an understanding of how adaptive co-management techniques can help solve problems that involve complex environmental and human infrastructure issues and provide some observations regarding the effectiveness of the three Highway 89 wildlife crossing structures that can be applied elsewhere.

The adaptive co-management concept and WCS evaluation techniques will be discussed in the literature review and applied to investigation of the H89ST's pursuit of the Highway 89 crossing structures and following projects. The program evaluation utilizes a "mixed method" approach incorporating archival research on WCS efforts, analysis of available wildlife camera trap photos and carcass removal data, and semi-structured interviews of representatives of H89ST members. The interviews were conducted and analyzed pursuant to best practices, as discussed in the methodology section of this thesis.

## Literature Review

The need for and benefits of wildlife crossing structures (WCS) in reducing wildlife-vehicle collisions and facilitating wildlife habitat connectivity has been well documented in recent years (Corlatti, et al., 2009, Huijser et al., 2008). A primary argument for constructing WCS is based upon wildlife-vehicle collision estimates. A 2008 Report to the US Congress from the Western Transportation Institute at Montana State University states that from 1990 to 2004, the total number of reported motor vehicle crashes in the U.S. was relatively steady at ~6 million per year, whereas the number of reported animal vehicle collisions increased by 50% over the same period, from less than 200,000 per year in 1990 to ~300,000 per year in 2004 – accounting for about 5% of all vehicle collisions nationwide. These collisions caused over 200 human fatalities and an estimated 26,000 injuries per year in the US, and cost \$6 to \$12 billion per year for law enforcement, emergency services and vehicle repair (Huijser et al., 2008). In 2017, 6,600 wildlife-vehicle collisions were reported to the California Highway Patrol, at an estimated damage cost of \$307 million (Shilling et al., 2018).

In addition to the damage caused directly by collisions, research has shown that roads create barriers to wildlife passage to locate water, food, mates, and shelter. The construction of Interstate 84 in Idaho in 1969 provides a stark example of the potential effects of highways on migratory deer. The new highway bisected the migration corridor for a large mule deer herd, and there were no provisions for wildlife crossings. Deer mortality skyrocketed and starvation soon became a problem because the highway kept the deer from reaching their winter feeding grounds. By 2001, the deer population was estimated at 1,500 animals, down from 4,000-5,000 in the 1960's (Oregon Metro., 2009). Other road barrier effects can include a loss of genetic

diversity among species with low populations, as illustrated by the near extinction of mountain lions in the Santa Monica Mountains due to being hemmed in by freeways (Benson et al., 2019).

**2.1 Types and Features of Wildlife Crossing Structures:** WCS generally come in two forms: undercrossings (including box or pipe culverts and spans under bridges), and overcrossings.

Corlatti et al. (2009) report that the first wildlife overcrossings were built in France and other European countries beginning in the 1950's. There is little documented evidence regarding when the first structures in the U.S. were built, however, it is fair to say that very few were built before 2000. The Corlatti article mentions an experimental undercrossing for frogs built in Davis, CA in 1995, and one of the first wildlife overcrossing in the U.S. was reportedly built in Florida in 2000. Overall, WCS have been found to be successful in providing landscape permeability for wildlife and in reducing wildlife-vehicle collisions. For example, in Banff National Park, Canada, a three-year study of two overcrossings and eleven undercrossings found that overcrossing structures that were high, wide, and short in length were preferred by grizzly bears, wolves, elk, and deer, and that undercrossings were preferred by black bears and mountain lions (Clevenger & Waltho, 2005). As of 2017, ongoing monitoring data showed that among large carnivores, mortality rates had declined by 50 – 100% and mortality rates for elk to almost zero, compared to 100 elk-vehicle collisions per year in the mid-1990s (Dickie, 2017).

With respect to preferences and use of crossing structures by ungulates, Gagnon et al. (2011) undertook a study comparing six large bridge-style underpasses in Arizona for a period of six years and compared their use among animal species, including elk, white-tailed deer, and mule deer. The authors found that different species preferred different structures and noted that different

species' adaptation rates to the structures were related to differences in home range sizes and exposure to the crossing structures. As a result of this study, the authors recommend that underpasses have clear visibility from one side to the other, and substituting underpass side walls with sloped earthen walls in place of vertical walls with ledges where possible to minimize noise and concerns about predators lurking on high ledges. The authors also note that deer like dense vegetation cover (trees) near the entrances to underpasses (Gagnon et al., 2011).

More recently, Simpson et al. (2016) compared overpasses and underpasses at two sites along US93 in northeastern Nevada, within the range of a migratory mule deer herd. This highway has a daily traffic volume of 2,100 to 2,400 vehicles per day – compared to H89, which is estimated to have a volume of approximately 5,000 vehicles per day. The underpasses are cylindrical corrugated metal pipe structures, like the structure at Kyburz Flat. The Nevada structures have exclusionary fencing and six escape ramps (or “jump-outs”) per site. The authors found that even after three years, passage rates for mule deer were greater at overpasses irrespective of location: “Most mule deer that approached an overpass continued over the structure, versus the greater proportion of individuals that hesitated and retreated from the underpasses.” The authors note, however, that another study by Sawyer et al., (2012) reported high use of concrete box underpasses by mule deer.

WCSs are expensive to build, particularly when they are designed and built as a “retrofit” project, rather than integrated into new road construction. The following Table 1f provides estimates from the Colorado Department of Transportation as of 2015, and these are in line with the costs reported for the Highway 89 underpass WCS. Note that the overpass cost estimate below is for a “single-bridge” style.

**Table 1. Initial Costs & Annual Maintenance of Wildlife Crossing Structures**

Wildlife Items	Initial Cost USD\$ 2015	Annual Maintenance Cost (USD\$ 2015)	Source
Overpass	\$2,059,210 ea.	\$3,363 ea.	CDOT (2016)
Underpass	\$1,569,271 ea.	\$3,363 ea.	CDOT (2016)
Deer Fence	\$153,785 ea.	\$1,657 per mile	CDOT (2016)

*Table 1. Source: Wilkins, D.C. et al. (2019).*

Although they are costly, crossing structures are cost effective based on estimating the annualized “break even” cost of building and maintaining such structures (including fencing) versus the cost associated with a deer-vehicle collision. In 2007, this annual cost was estimated at \$18,123 per year, which equated to the costs associated with 3.2 deer/kilometer (~2 deer/mile) collisions per year:

**Table 2. Threshold Values for Mitigation Measures to Reduce Deer-Vehicle Collisions**

Mitigation Measure	\$ Cost (2007) / Year	Deer / Km / Year
Rate <sup>1</sup>	3%	3%
Fence	\$6,304	1.1
Fence, underpass & jump-outs	\$18,123	3.2
Fence, under & overpass, jump-outs	\$24,230	4.3
ADS <sup>2</sup>	\$37,014	6.4
Gap, ADS & jump-outs	\$28,150	4.9
Elevated roadway	\$3,109,422	470
Road tunnel	\$4,981,333	752.8

*Table 2. Source: Clevenger & Ament, (2017).*

Importantly, funding has recently been approved for wildlife structures both at the State and federal level. In 2021, California budgeted \$61.5 million for wildlife crossing projects (High

Country News, 2021) and HR 3684, the federal Infrastructure Investment and Jobs Act passed in 2021, includes \$350 million to construct WCS (Wildlands Network, 2021).

**2.2 Placement and Evaluation Methods for Wildlife Crossing Structures:** Studies have discussed “best practices” for the placement of WCS, including analysis of wildlife-vehicle collision data and animal telemetry collar tracking data. With respect to the optimal spacing of WCS along roadways, studies have relied primarily on determining the home ranges of species using radio-collared animals. Bissonette, & Adair (2008) concluded that placing wildlife crossings for white-tailed and mule deer (by far the most frequently hit animals on North American roads) about one mile (1.6 km) apart in hotspot areas where deer cross the road frequently would improve highway safety and ensure ease of movement for over 71% of the species. However, while placement of structures at known animal crossing points and collision “hotspots” is important for effectiveness, the practicalities of topography, adjacent property ownership and wildlife access play a limiting role in the location and design of WCS.

By far the most widely used method for prioritizing locations of WCS is the collection and analysis of wildlife-vehicle collision data documented by state departments of transportation. From this data, “hotspots” of wildlife-vehicle collisions can be determined and prioritized for placement of WCS. Unfortunately, roadkill data are sometimes not accurate to a fine degree in terms of location (mile marker), and roadkill is generally recorded only for larger mammals such as deer and bear. Another method of collecting wildlife-vehicle collision data in recent years has been through “citizen scientist” websites, such as the California Roadkill Observation System (CROS), where volunteers record observations of identifiable roadkill, and upload the data

(species, date, time and location). Over 65,000 observations have been posted to the CROS website to date (Ha & Shilling, 2017). Figure 3 below shows observations for the northern Sierra, including Highway 89. The left-side map shows that Highway 89 had a reported density of ~10-12 roadkill observations per mile for the period from 2009 – 2015, and the right-side indicates ~.2 – 1 per mile for the period from 2016 – 2020.

**Figure 3. CA Roadkill Observation System (CROS) Reports for 2015 and 2020: Hwy 89**

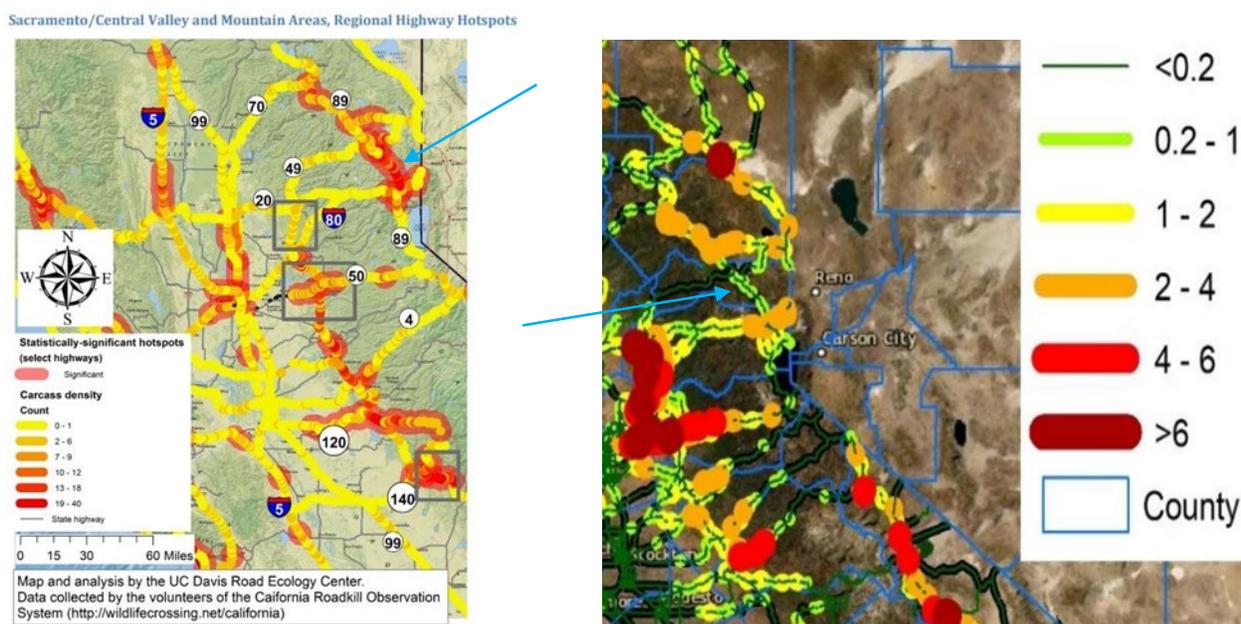


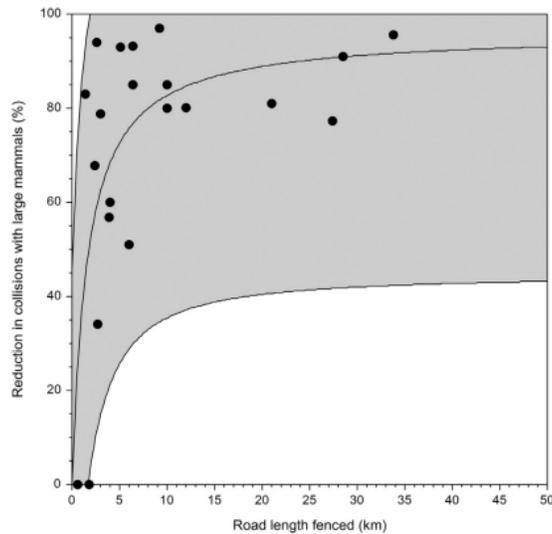
Figure 3. Left, Source: Shilling, UC Davis Road Ecology Center (2016). Right, Source: Shilling, UC Davis Road Ecology Center (2021). Arrows point to Highway 89 in Sierra County.

Research also emphasizes the need for post-completion monitoring of wildlife crossings to assess effectiveness and increase knowledge about this conservation tool (van der Grift et al., 2013, and Simpson et al., 2016). According to van der Grift, “As argued by Roedenbeck, et al. (2007), the optimal study design is a replicated BACI (Before-After-Control-Impact), where data are collected before and after road mitigation, both at sites where mitigation measures are being

taken... and at sites that are similar to these sites but where no mitigation measures are taken (control sites)...Control sites are important to ensure that changes to the measurement endpoint can reasonably be attributed to the mitigation measures.” (van der Grift et al., 2013) Wildlife-vehicle collision data from before and after the installation of WCS and attendant exclusion fencing can be compared with nearby, comparable sites where no WCS has been installed.

In several evaluations of WCS effectiveness, it has been found that after installation, wildlife-vehicle collisions are reduced at the location of the structure and surrounding fencing but increase at the fence ends. Collisions can also increase in other (control) areas over time, and this is often attributable to increasing traffic on roadways. For example, post-construction evaluations of a series of WCS on US 93 in Montana compared wildlife-vehicle collision data and wildlife crossing use before and after the structures were completed and found that for the northern stretch of highway, the mitigation measures reduced collisions with large mammals by 71% based on carcass removal data. “Interestingly, collisions increased in the unmitigated “control” road sections”. The reduced effectiveness of short, fenced road sections was related to fence-end effects that resulted in a concentration of collisions at and near fence ends “ (Huijser et al. 2016). Figure 4 below illustrate the study’s findings that fencing of at least 5 kilometers surrounding a crossing structure is effective at reducing collisions by at least 80%.

**Figure 4. Effectiveness of Wildlife Fencing in Reducing Wildlife -Vehicle Collisions**



**Fig. 1.** The effectiveness of the 21 mitigated road sections with varying fence lengths in reducing collisions with large mammals. A Michaelis-Menten function (black line) was fitted to the data ( $Y = 96.07 * X / (1.62 + X)$ ) with associated 95% confidence interval (gray area).

*Figure 4. Source: Huijser et al. (2016)*

As previously discussed, another way to assess the effectiveness of WCS is to monitor them for several years with camera traps to document which species are using the structures. Animals commonly approach a crossing structure to assess it before attempting to pass through, and it can take several years before prey species such as deer become confident in using them. In the case of the Nevada crossing structures study, the authors found that over a period of four years (eight seasonal mule deer migrations), successful passage through underpasses improved from 23-34% in the first year to 64%-86% by year four. In contrast, overpasses had passage rates in the range of 94 to 96% in year one, and stayed consistently high (Simpson, et al. 2016). A similar study of wildlife underpasses in Arizona found that over a period of ~5 years, the passage rates for all species was 72.4% (Gagnon et al. 2011).

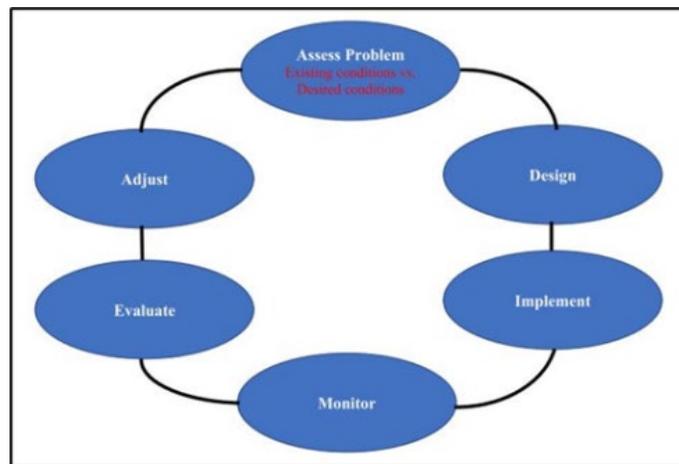
**2.3 Adaptive Co-management:** In undertaking the planning of WCS, some authors have discussed the need for a multi-disciplinary, multi-jurisdictional approach to bring together information, resources, and support for these projects. (Ament et al., 2018, Clevenger & Ament, 2017). This approach to environmental problem-solving has been termed adaptive co-management (ACM).

An on-line search for articles on adaptive co-management from the J. Paul Leonard Library at San Francisco State University yielded 5,851 entries, including many articles on the subject. Research dealt with the definition, components and key requirements for the practice of successful ACM. Articles also discussed applications of ACM from various parts of the world including the US and Canada, Europe, Africa and Indonesia. Nearly all the articles dealt with environmental issues, and many dealt with large-scale natural resource areas such as marine ecosystems and fisheries, and forest management. This review of the literature draws from five articles and one book selected either because they provided an analysis of the components of ACM, or because they analyzed US federal programs utilizing ACM – and are thus more comparable to the subject of this thesis.

According to Williams (2011), the concept of adaptive management has existed for several decades. One of its earliest articulations in natural resources literature was by Berton and Holt (1957), who described adaptive decision-making in fisheries without calling it adaptive management. A generation later Holling (1978) and Walters and Hilborn (1978) provided the name and conceptual framework for adaptive resources management” (Williams, 2011). Adaptive management developed as a response to complexity and uncertainty with respect to environmental and natural resource issues and involves “learning by doing”. It is an iterative

process which includes components of scoping or assessing problems and opportunities, designing solution options and implementing them, monitoring and evaluating results, and adjusting or trying new solutions as necessary (Plummer, 2009). Thus, the experimental design, follow-up monitoring of a policy or other solution, and re-design for the next implementation round is useful for situations involving ecosystems, where there are numerous factors at play and uncertainty affecting the environment or resource. Lien et al. (2021) summarizes the functions of adaptive management in the following Figure 5:

**Figure 5. The Adaptive Management Cycle – US Forest Service Policy**



*Figure 5. Source: Lien, et al. 2021.*

As a separate idea, co-management – or collaborative management - “captures the idea that rights and responsibilities should be shared among those with a claim to the environment or a natural resource” (Plummer, 2009). While early definitions focused on power sharing between state and local (or indigenous) resource users, the concept has been broadened to include an array of participants and has been applied across several resource contexts. Plummer (2009) argues that the co-management process can be viewed as three stages: 1) independence, when

interactions between actors (i.e.. government agencies, landowners, stakeholders) does not occur, 2) association, when actors begin to interact, with resource agencies investigating technical aspects, assessing the resources, and becoming cognizant of issues surrounding the resource, while other stakeholders engage in communication, articulate resource values that lead to a shared visions, and all groups begin to learn about the differing perspectives of others; and 3) integration, when a path is selected, the group collectively undertakes a task and shares the consequences of their actions.

In merging the concept of adaptive management and co-management, Armitage et al. (2008) states that: “This method draws explicit attention to the learning (experiential and experimental) and collaboration (vertical and horizontal) functions necessary to improve our understanding of, and ability to respond to, complex social-ecological systems (Armitage, et al. 2008). Williams asserts that the components of adaptive management consist of stakeholder involvement, defining objectives, management actions, modeling to link actions to resource consequences, and to assess alternatives, and monitoring (Williams, 2011). It is an iterative cycle that then repeats.

Plummer has identified two kinds of variables that can influence the process of adaptive co-management. Exogenous variables originate outside the network of actors involved in the process and are outside their direct control. Exogenous variables include ecosystem changes or resource alterations; government policies and resource support or reductions; the social and political context, including factors such as culture, knowledge systems, and power; and meso-scale social and economic drivers. Endogenous factors originate within the network of actors involved, and include the networks, and links between individuals and organizations; assets

employed by actor organizations and individuals including social relationships of trust; natural capital (ecosystem services, for example), and physical and financial capital; and attributes of individuals including leadership and capacity for learning and change (Plummer, 2009).

The following three articles provide some insight into how the ACM process has evolved in the U.S. over the last three decades, and how it can shape environmental programs. While the articles pertain to federal programs, they are applicable to state programs and policies as well.

In the first case, Wilhere (2002) assesses the efficacy of the Endangered Species Act of 1973, which originally contained an absolute prohibition against the taking of endangered wildlife. This led to problems of implementation in that government agencies - US Fish & Wildlife Service and National Marine Fisheries Service - were reluctant to enforce a law that could punish a wide range of otherwise lawful activities or unfairly penalize landowners, whereas some landowners/fishermen were incited to be uncooperative out of fear of restrictions. In 1982, the Act was amended to encourage landowners to cooperate in preserving endangered species, by granting permits that allowed for incidental taking of such species provided that the taking could be mitigated. The permits were granted in tandem with negotiated Habitat Conservation Plans (HCPs), which spelled out measures that the landowner would take in pursuing conservation goals. However, this was still not enough incentive to cooperate, and the HCPs were not used much until in 1994 a “no surprises” policy was issued which assured private landowners that the government would *never* require mitigation measures beyond that agreed to under the terms of the HCP. While this new policy was popular with landowners, the “no surprises” policy was decried by scientists and environmentalists as undermining the principles of adaptive management. In response, new regulations adopted in 1998 outline a range of

potential “foreseen” issues and mitigations that could be undertaken to address them. However, for *unforeseen* changes, the landowner will not be required to provide additional conservation measures. As a result, the author concludes that this is an adaptive management policy is only partially effective (Wilhere, 2002).

In the second example of this process, Butler & Schultz (2019) discuss the US Forest Service’s Collaborative Forest Landscape Restoration Program (CLFRP), which followed the adoption of the Forest Landscape Restoration Act of 2009 “...to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes”. A primary motivation for this act was to reduce the risk and occurrence of major wildfires in national forests. In the book’s introduction, the authors lay out critical components of the “collaborative governance” and emphasize the critical influencing factors of trust, accountability, and capacity. “Environmental restoration” as a concept can galvanize collaborative groups – but it is also a contested idea. The authors discuss how science can be used to inform decisions with collaborative contexts, generating new information through monitoring, and thus help resolve conflicts (Butler & Schultz, 2019).

A third article by Lien et. al. (2021), discusses a key ingredient for the success of ACM programs, which is Trust. The authors conducted semi-structured interviews of ranchers who obtain allotments for the use of rangeland from the US Forest Service in Arizona and New Mexico for livestock grazing. Allotment management plans are designed as adaptive management tools, in which ongoing monitoring of rangeland conditions is undertaken, and adjustments to the grazing allotment are collaboratively made on an annual basis. The research question was whether implementation of adaptive management decreases conflict between the

allotment holders and the Forest Service. The authors found that robust monitoring programs, clear lines of communication, and trust built over time could reduce conflict, and were key in the successful deployment of this program (Lien et al., 2021).

Williams summarizes the key issues to be considered in deciding whether to use adaptive management technique for environmental issues as follows: 1) is there substantial uncertainty about the impacts of the management action, 2) is there a realistic expectation of reducing uncertainty, and 3) can that reduction in uncertainty be expected to improve management? He advises against undertaking adaptive management in cases where there is little uncertainty about what actions to take and what outcomes to expect, where no effective monitoring program is possible, and where there is no mechanism for feedback of monitoring and assessment into management strategy (Williams, 2011).

This raises a question as to whether the “adaptive” component of the adaptive co-management technique is applicable to wildlife crossing structures. As noted above, researchers in this field uniformly advocate for assessing locations for wildlife crossing structures by using wildlife collision and other data, as well as follow-up monitoring to assess the effectiveness of the structures. However, researchers also argue that crossing structures are generally *proven* to be effective in reducing wildlife mortality rates. In addition, these structures are costly to build, and cannot be easily moved. So, does the “adaptive” part of this strategy apply to wildlife crossing structures? Literature appears to suggest that the answer is “yes”, because some modifications to existing structures *can* be made as needed, including those to fencing, escape ramps (“jump-outs”), vegetation cover near entrances, and even minor modifications to the structures themselves such as ledges or soundproofing.

Having made the argument for the “adaptive” side of ACM, an article by two prominent experts in the field from the Western Transportation Institute at Montana State University stresses the “collaborative” or co-management approaches: “... We also suggest partnerships be used as a tool to advance wildlife crossing structures... A systematic approach to mitigating wildlife impacts from highways is challenging because no single agency is responsible for sustaining movement of animals across the landscape... many local, state, tribal and federal agencies need to collaborate on projects where their missions overlap (see Beckmann et al. 2010).” (Clevenger and Ament 2017). The authors also cite the need to creatively leverage funding and opportunities to build crossings, as well as the opportunity for federal agencies to facilitate coordination among adjacent states for the protection of species.

These recommendations are echoed in the Montana Wildlife & Transportation Summit Final Report (Ament, 2018), which lays out the following six themes: 1) Working Together: creating a collaborative structures to plan and implement wildlife accommodations, including developing an MOU between the state departments of Transportation and Fish, Wildlife & Parks; 2) Planning: creating a statewide wildlife & transportation work plan, that reflects local, regional and district efforts; 3) Policy and Legislation: develop policies to support collaborative efforts – including a non-governmental advocacy organization in this effort. 4) Priorities: compile and share information at local, regional levels to determine priorities and identify information gaps. 5) Education & Outreach: develop opportunities to engage the broader community in participating and supporting projects related to wildlife and transportation issues, and 6) Funding: research and develop funding mechanisms that add to traditional transportation program funds, including implementation, maintenance, and research and monitoring.

## Methodology

This thesis utilizes a “multi-method” approach to evaluate the effectiveness of the Highway 89 Stewardship Team’s approach to resolving the problem of wildlife-vehicle collisions on Highway 89. The primary method is a set of semi-structured interviews with six key informants from organizations involved in the H89ST process that led to the construction of the WCS. Key informants at Caltrans, the CA Department of Fish and Wildlife (DFW), Sierra County and the UC Cooperative Extension had previously been identified for research on the Highway 89 crossing structures. The other methods employed included an internet-based search for archival documents related to the H89ST’s efforts, and national and state programs and funding related to WCS and wildlife habitat permeability, analysis of available wildlife collision data for Highway 89 before and after the WCS were built, and analysis of available camera-trap data for the WCS to determine species use and WCS passage rates by wildlife. The latter two methods are meant to inform the interview questions and to assist in providing historical grounding and objectivity to the analysis. Both Caltrans and DFW supplied the highway wildlife carcass data and crossing structure wildlife camera data analyzed for this thesis.

The use of other research methods to inform and supplement interviews is common. In a review of 227 articles written using the interview technique for conservation issues, Young, et. al. (2017) found that in 70% of the papers incorporated other methods, such as document analysis, literature reviews and analysis of field data. Galletta, A. & Cross, W.E. (2013), also discusses multi-method study of archival materials including newspaper clippings, meeting minutes, and external studies to supplement interviews, noting that “Archival data provide a historical record of events, discourse, stakeholders, and images.”

**3.1 Archival Research:** A website search was conducted in 2021 for articles and documents pertaining to the Highway 89 wildlife crossing structures and other H89ST activities. The search focused on H89ST member activities and yielded a total of 28 articles and documents that were consulted for this thesis, including eight from the California Department of Fish and Wildlife (DFW), five from the California Department of Transportation (Caltrans), seven from USDA Forest Service and Tahoe National Forest, one from Sierra County Planning Department, three from the UC Berkeley Sagehen Field Station and UC Davis Natural Reserve System, two from the California Deer Association, and two news articles. In addition, 11 documents related to recent WCS federal and state legislation, funding and related wildlife habitat permeability initiatives were reviewed. Information from this search will be discussed in the “Results” section of this thesis.

**3.3 Semi-Structured Interviews:** The semi-structured interviews explore key informants’ views on the planning process, construction, effectiveness of the structures, and future priorities for the area. While the project and the team’s work have been highlighted in articles as mentioned above, the articles reveal little detail about the decision-making process that led to the installation of the underpasses, the choice of locations, how these projects may have fulfilled other goals of the team members and their organizations, how (and how much) communication was established among the team members, whether there was debate over these choices and how these debates may have been solved, i.e.. the “co-management” aspect of the project. In addition, the interviews attempted to elicit opinions about what was learned from the process of building these structures and subsequent efforts to monitor the effectiveness of the structures,

i.e.. the “adaptive” aspect of the project as well as thoughts for future modifications to the structures or additional wildlife-vehicle prevention efforts.

The process for conducting interviews is guided by the San Francisco State University’s requirements issued by Human and Animal Protections (HAP) in the Office of Research and Sponsored Projects (ORSP). The research protocol included a recruiting script delivered via email to the key informants, an informed consent document outlining the purpose of the interview and potential risks for the informants, and the list of interview questions for each of the key informants. These documents were also reviewed as part of a successful application for Determination of Exemption from review by the Institutional Review Board (IRB).

Informed consent and ethical review of the interview process is recommended by Young, et al. (2017), to minimize the level of personal intrusion, maintain anonymity of the interview subjects, securely store confidential data, and explain the purpose of the project. In addition, the authors recommend that interviews be “pilot tested” on knowledgeable persons (after ethical clearance) to check the interview questions for length , language suitability and potential sources of bias. One of the advantages of conducting a semi-structured interview is that it allows for a more conversational approach between the interviewer and key informant, including asking follow-up questions to responses given by the interview subject. While this allows for additional avenues of inquiry that the interviewer may not have anticipated, it also poses some danger that the interviewer may ask “leading” questions and thus interject bias into the interview. The interview questions were pilot-tested on January 17, 2022 with a reasonably knowledgeable person, and particular attention was paid to length of the interviews and potential bias due to “leading

questions”. The interviews took approximately one hour each and were deemed suitable in terms of length and objectivity.

Key informants from Caltrans, the CA Department of Fish and Wildlife (DFW), UC Cooperative Extension (retired), the US Forest Service/Tahoe National Forest, and Sierra County were contacted directly via email to determine their willingness to consider being interviewed for this thesis, and representatives of the California Highway Patrol and UC Berkeley Sagehen Research Station were recruited via “snowball sampling” to request a referral to a person who either had participated in or had familiarity with the history of the Highway 89 Stewardship Team and the WCS on Highway 89. Ultimately, there were six interview participants: the Highway Patrol and UC Berkeley were not included due to lack of knowledge about the projects, while two employees of the USFS were included. All key informants received the recruitment script and signed the informed consent documents. Interviews were held via internet/Zoom or by telephone, and the interviews were recorded and transcribed and stored on the author’s personal computer to ensure security. The names and position titles of key informants are excluded from this thesis to protect their privacy.

The interviews included four “common” questions that were asked of all key informants at the outset of the interview, as well as another set of five common questions at the end of the interview. In the middle segment of the interview, questions were tailored to address the knowledge that each brought to the process and questions specific to the goals and activities of their respective organizations. The order of the interview questions was designed to follow the recommendations of authors in this field, particularly Galleta (2013). This author recommends that interviews begin by establishing a level of comfort with the participant by asking general

questions and ensuring participants of their rights under the informed consent. In the opening phase, questions are broad to encourage the interview subject to speak from experience and are also geared toward establishing the overall thematic goals of the interview. In the middle phase of the interview, questions are more specific as they relate to the research question. The interviewer can “loop back” to the participant’s opening narrative as it connects with the more specific questions. The concluding segment of the interview poses questions that offer the opportunity to further explore the opening narrative in relation to the theory-driven questions, and again provide clarification of earlier remarks. The interviewer conveys a sense that the interview is wrapping up, ask for any final thoughts, and thanks the participant for their contributions to the research. The interview questions are attached to this thesis in Appendix A.

The interviews ranged in length from approximately 45 minutes to over an hour. Following the interviews, the recordings were transcribed and analyzed for themes and ideas. Thematic patterns were documented for each interview and labeled as “codes”. Themes in the early stages of analysis are intended to be descriptive of the data, rather than interpretive or relating theory. As codes emerge throughout the analysis of the interviews, some codes may be combined and others discarded themes which are common across the interviews are then related back to the literature review and research question.

**3.4 Wildlife Crossing Structure Monitoring Data:** Wildlife carcass data has been collected by Caltrans maintenance personnel on Highway 89 in Sierra County each year from 1979 through 2019. The data are sorted by date between deer and “unknown” (other) animals, and the deer data is sorted between does, bucks and fawns. The data is also ordered by highway post-mile and

extends from post-mile 1 at the southern Sierra County line to post-mile 7, including the three WCS locations plus their attendant fencing. The analysis compares carcass collections at the three WCS sites before and after installation, and also compares this data to “control” area data to determine the effect of the WCS on reducing wildlife-vehicle collisions, after the methods of van der Grift, et al. (2013) and Gilhooly, et al. (2019). Because of the relatively low numbers of carcasses collected, this comparison is made in terms of simple percentage changes, rather than undertaking statistical analyses of the data.

Motion-activated cameras (“camera traps”) were installed on both sides of the Kyburz Flat WCS for ten years (2009-2018) following completion of the structure, and the raw photo data was provided by a former H89ST member at the request of the DFW. Photos from the Sagehen Flat structures were also supplied by Caltrans for five years following completion of the structures (2016-2020). The photos were analyzed to determine the numbers of deer and other animals that approached the structure, and to calculate the “passage” rate of animals that travel through the structure, after the methods of Simpson, et al. (2016) and Gagnon, et al. (2011). More information regarding the method of analysis is included in the Results portion of this thesis, and the findings are also compared to those of other WCS post-completion studies in the Discussion.

## Results

### 4.1 Archival Research:

History of the Highway 89 Wildlife Crossing Structures - The following history of the crossing structures on Highway 89 is attributable primarily to articles written during the period from 2005-2013 (Jacobson & DeLasaux, 2005, and Holm, 2013), although several other informational pieces have also been written about this project. According to both articles the process began in 2002, when Sierra County contacted state and federal agencies about the high rates of deer mortality on the Highway 89. The Sierra County Board of Supervisors also submitted an application for a Caltrans Transportation Enhancement grant to mitigate wildlife-vehicle collisions. The Highway 89 Stewardship Team (H89ST) members included representatives from the CA Department of Fish and Wildlife (DFW), the US Forest Service Pacific Southwest Research Station, Caltrans, the Sierra County Fish & Wildlife Commission and Sierra County Board of Supervisors, the UC Cooperative Extension, the UC Berkeley Sagehen Creek Field Station, and the California Deer Association. According to Sandra Jacobson of the Forest Service Pacific Southwest Research Station “The Pacific Southwest Research Station was requested to organize, lead and teach the new Highway 89 Stewardship Team until local individuals could take over” (Jacobson & De Lasaux, 2005).

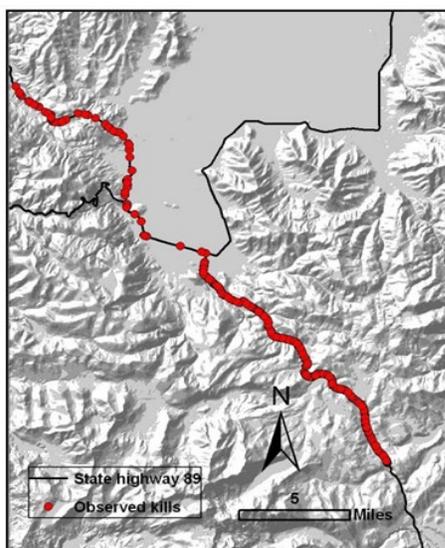
Organization, Research & Planning Efforts H89ST - Several of these organizations were already working independently on research and other efforts related to the wildlife-vehicle collisions and habitat planning including: 1) Caltrans’s effort to systematically collect wildlife carcass data on Highway 89 that began in 1979, 2) research on the relationship between roadside forest thinning and wildlife-vehicle collisions by UC Cooperative Extension, 3) grant

applications to study the relationship between wildlife collisions and placement of de-icing salt on highways by the Sierra County Fish & Wildlife Commission, 4) efforts by the USFS Tahoe National Forest (TNF) to utilize the Caltrans data to preserve wildlife connectivity and habitat, and 5) California Department of Fish & Wildlife efforts to monitor deer migration corridors and maintain wildlife preserves in the County. The team agreed informally on a set of goals, which included increasing traveler safety by decreasing deer/vehicle collisions and increasing habitat connectivity for all wildlife species. Other goals included public education, and applied research and monitoring. During that time Sierra County applied for and received a \$132,000 Title III grant to involve local schools in the research and monitoring efforts. The California Deer Association also provided a \$5,000 grant to the team member for expenses. The team's goals were described as a "three-pronged approach": research, mitigation, and education.

In 2003, the team began to plan how to achieve its objective to reduce wildlife-vehicle collisions on Highway 89 and improve habitat connectivity. While not explicitly stated in the articles, it appears that the H89ST settled on the installation of wildlife crossing structures as a primary objective early on. The starting point for this work was the Caltrans data that had been collected for 25 years. The data were analyzed to identify hotspots of wildlife-vehicle collisions along the highway. An article written shortly after this period identified nine hotspots involving wildlife collisions along the 33 mile stretch of highway using data from June 1979 to October 2005 and calculated that the mean number of wildlife-vehicle collisions along this route was 25.7 kills/mile over the period, or the equivalent of one kill per mile per year (Bissonette, 2007). However – as illustrated in Figure 6, the data was not entirely clear. Bissonette explained that due to the sheer amount of data over such a long period, overlapping hotspots made it difficult to

pinpoint where the wildlife-vehicle collisions occurred. Also, as noted by the DFW, while some deer follow drainages, others move across the landscape in a sheet flow pattern, and this movement pattern is common in areas that lack barriers, such as steep canyons (Wong, 2010). As a result, in flatter landscapes such as those surrounding Kyburz Flat, wildlife-vehicle collisions can take place over a wider range of miles.

**Figure 6. Location of Deer-Vehicle Collisions on Highway 89, Sierra County CA**



*Figure 6.. Source: Bissonette, J.A.2007..*

The team also utilized the Caltrans carcass data in conducting what Jacobson & De Lasaux called a “mid-scale connectivity analysis” modeled after Ruediger and Lloyd (2003). The team also considered habitat quality maps from the US Forest Service, mule deer movement information from the California DFW, local experience and evidence from field work. During the planning stage, the team limited its focus to 15 miles between the southern Sierra County line and Sierraville because of the Caltrans grant applications submitted by Sierra County. While the

team did not have an established budget when it began to consider solutions, it determined that the solutions would have to be “cost effective”: “For example, the only mitigation solution currently available as a feasible engineering design in some of the hotspots would be an overcrossing; we rejected this option due to its high-cost relative to the traffic volume expected in the next 50 years” (Jacobson & De Lasaux, 2005). Holm took a slightly different view that “Though we had early hopes of the large overpasses that have successfully been installed in Banff, Canada, we did not have the topography or the funds to make it happen.” (Holm, 2013). Holm noted that pipe arch underpasses had been previously built on Highway 395 north of Reno, Nevada, and on Interstate 80 outside of Truckee, so this was a familiar design concept.

In 2004, the team also undertook a “Value Analysis” based on a process used by Caltrans for road improvement projects. As seen in Figure 7 below, the team utilized eleven factors and ranked these factors in order of importance before applying them to the sites themselves. Construction “Feasibility” and “Habitat quality” were the most important ranking factors for the team, and aesthetics ranked the lowest, followed by environmental impact (of the mitigation itself), followed by safety: “...the team reasoned that functional mitigation would provide safety benefits and that mitigation options that provided safety benefits (but not ecological benefits) were less desirable.” (Jacobson & DeLasaux, 2005).

**Figure 7. Modified Caltrans Value Analysis Performance Criteria**

C4		f1														
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
1	Performance Criteria Evaluation															
2		Feasibility	Aesthetics	Maintainability	Environmental Impact	Cost-effectiveness	Land ownership	Urgency	Habitat Quality	Multiple-species	Safety	Human Disturbance				
3	Criteria	A	B	C	D	E	F	G	H	I	J	K	Total	Percent		
4	A Feasibility	A	A	A	A	A	A	A	A	A	A	A	10	19		
5	B Aesthetics		C	D	E	F	G	H	I	J	K		0	0		
6	C Maintainability			C	E	F	G	H	I	J	K		2	4		
7	D Environmental Impact				E	F	G	H	I	J	K		1	2		
8	E Cost-effectiveness					E	G	H	I	J	K		4	7		
9	F Land ownership						G	H	I	J	K		3	6		
10	G Urgency							H	I	J	G		7	13		
11	H Habitat Quality								H	H	H		10	19		
12	I Multiple-species									I	I		9	17		
13	J Safety										J		2	4		
14	K Human Disturbance												6	11		
15													Total	54	102	<- rounding error

*Figure 7. Jacobson and DeLasaux, 2005.*

Kyburz Flat WCS Funding: In 2004, as the team was pursuing its study of Highway 89, Caltrans notified the County that it had approved a \$720,000 grant. At this time the team determined that it would be more effective to locate the structure south of a “side road” (likely Hennes Pass Road) that diverted a significant amount of traffic from Highway 89. As a result, the team narrowed its focus to the southern 4-5 miles of Highway 89 within Sierra County for mitigation projects (Jacobson & De Lasaux 2005). The team narrowed its choices to three locations and submitted them to Caltrans for review. Caltrans determined that one of these options could be constructed within the approved \$720,000 budget: the Kyburz Flat crossing, which was the first choice of the Team.

Kyburz Flat Design & Construction: In 2006, Caltrans began the process of obtaining environmental permits, and design and bidding for the project (Holm 2013). At this time, the DFW also began to collar deer for the Loyaltan-Truckee Deer Herd study, which has continued to the present day. Construction was underway in 2007, and the Kyburz Flat project was completed in September 2008. The location of this structure is at Sierra County mile post SIE

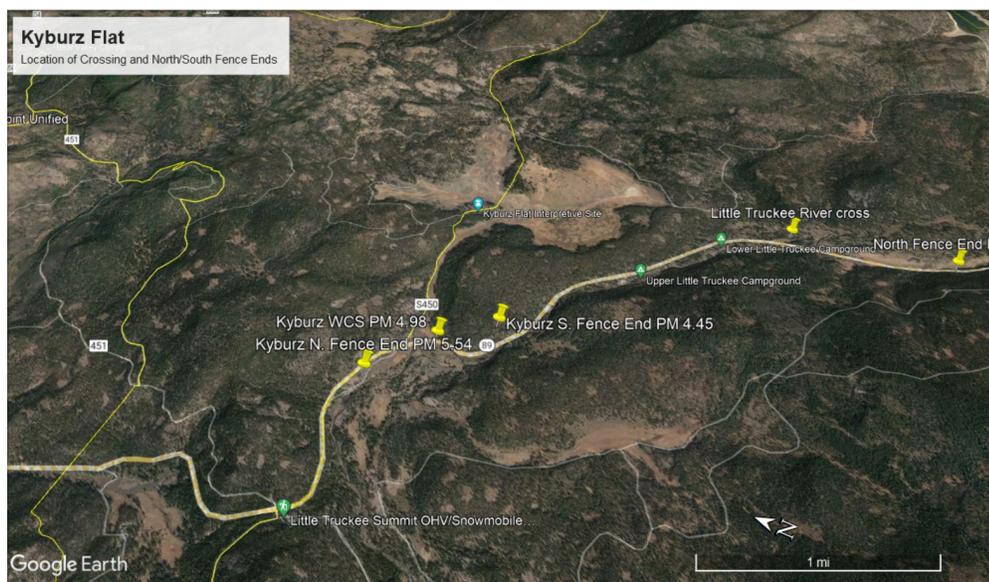
4.977. The steel pipe structure measures ~12 feet high by 19 feet wide (ROUTE089, 2022), although it has a layer of substrate, which reduced the height to 10 feet or less. The community had a dedication celebration in June 2009, and the site was used for three years for summer educational projects.

**Figure 8. Kyburz Flat Wildlife Crossing Structure Under Construction**



*Figure 8. Source: Jacobson, Undated Presentation*

**Figure 9. Kyburz Flat Wildlife Crossing Structure & Fence-ends**



*Figure 9. Source: Google Earth and Caltrans*

In early 2008 the H89ST received a second Transportation Enhancement Grant to erect fencing and jump-outs on either side of the highway at Kyburz Flat (Holm, 2013). However, the fencing was not installed until 2013 (Loyalton-Truckee Deer, 2022). The Kyburz fencing extends from post mile SIE 4.45 to 5.54. The article by Wong (2010) quoted the H89ST as follows:

“Each section (of fencing) will be made from different materials to learn how effective each is at channeling wildlife. “Different species have different fence-foiling behaviors. ..The durability of each type of material is also a factor. Winter is hard on fences here... The difficulty of meeting these criteria, plus the high cost of fence installation and upkeep, creates opportunities for the H89ST to explore alternative methods of redirecting wildlife... The Highway 89ST is just as interested in conducting road ecology research as it is in building crossing structures.”

Notably, the State Highway Operation and Protection Program (SHOPP 2020) budget as of June 2021 included a project to repair damaged wildlife fencing, place rock slope protection to stabilize the embankment, and pave inside wildlife crossing to create water channel at a total cost \$1.6 million. The fence repairs extend from post miles SEI .6 – 5.1 encompassing the exclusion fencing for all three structures (SHOPP, 2020).

Sagehen Grade Wildlife Crossing Structures: Much less has been written about the planning process for the Sagehen Grade structures. DeLasaux (2012) indicates that Caltrans data revealed both the Kyburz Meadow and the Sagehen Grade areas as wildlife-vehicle collision hotspots at the time of the H89ST’s site analysis. In a companion article, Jacobson (2012) also noted that topography was a major consideration: “An overpass simply would not have worked with the slope on Sagehen Grade, yet the two drainages there are natural travel corridors and can rather readily handle underpasses.” Also, the undated presentation by Jacobson noted that the Sagehen Pass was identified through anecdotal evidence by local travelers as an area of many

sightings and collisions. Finally, there are indications that the H89ST was looking to experiment with twin structures, in terms of comparing flooring materials and soundproofing (Tahoe National Forest: H89ST, 2014).

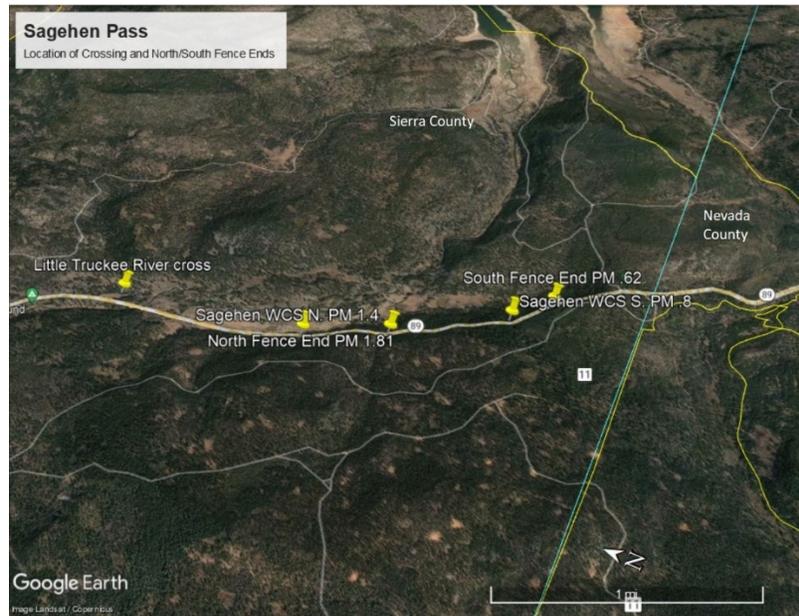
The Sagehen Pass Structures project included a pair of 10 foot high by 12-foot-wide concrete box culverts, four escape ramps – or ”jump-outs”, and 1.3 miles of deer fencing. The fencing runs between the two structures, which are located at SIE .8 and SIE 1.4 at the southern end of Sierra County. According to the ROUTE089, 2022 website post, the project cost \$2.8 million, and was funded by the State Highway Operation and Protection Program (SHOPP) budget. The article also stated that Caltrans environmental staff, in conjunction with the H89ST would monitor the undercrossings for three years to study their effectiveness; in fact, the structures have now been monitored for over 5 years by Caltrans). Construction for the project began in May 2016 and both structures were in use later that year.

**Figure 10. Sagehen Wildlife Crossing Structures: Pre-construction**



*Figure 10. Source: Jacobson, S, Undated Presentation.*

**Figure 11. Sagehen Wildlife Crossing Structures & Fence Ends**

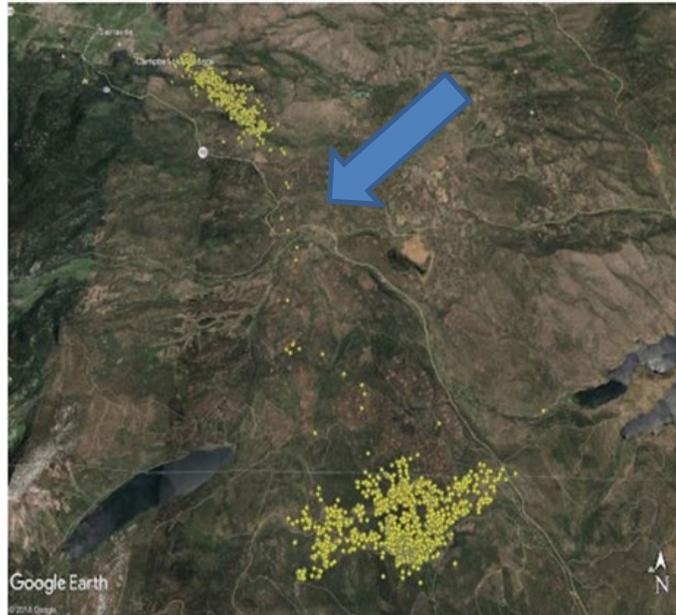


*Figure 11. Source: Google Earth and Caltrans.*

Finally, in her undated Presentation “The Highway 89 Stewardship Team: Helping Wildlife Move Across the Sierra”, Jacobson outlined the following future challenges for the H89ST: “1) Succession planning, 2) Funding, 3) Scope creep, and 4) Suitable research staff.” Jacobson’s list of “challenges” suggests that some of the original team members were preparing to retire or move on - as she subsequently did - and that efforts to engage researchers to evaluate and experiment with the structures were problematic.

Related activities in Sierra County: The following activities are related to the H89ST’s work on Highway 89. They can arguably be seen as “adaptive” aspects to the Highway 89 wildlife crossing structure project, and they speak to the motivation of the team’s participants.

**Figure 12. Loyalton-Truckee Deer Herd Study: Deer Collar Radio tracking**



*Figure 12. Source: Deer #3Fi35, Sagehen Blogspot, 2020. This aerial photo shows data from one deer, which was radio collared as part of the Loyalton Truckee Deer Herd Study, in 2019. This deer appears to travel between its summer grounds at Sagehen Pass the west side of Highway 89 to winter grounds on the east side of the highway via the Kyburz Flat area, possibly through the crossing structure, as indicated by the arrow.*

Loyalton-Truckee Deer Herd Study: According to the CA Department of Fish & Wildlife, the deer herd study was started to provide evidence of routes that migratory deer were taking from their summer to winter feeding grounds, to help find the best locations for the Highway 89 crossing structures (Loyalton-Truckee Deer, 2021). In 2006, as the Kyburz Flat WCS was getting underway, the DFW obtained funds to begin its deer herd study by purchasing 10 radio collars to place on deer in the Sierra Valley sub-unit of the Loyalton-Truckee deer herd. The number of collared deer had expanded to 15 by 2012, and ultimately 87 deer have worn collars, which now include satellite collars. Figure 12 above shows data from one deer collar in 2019. The data from the collar study showed that 26 (~30%) of the deer had crossed Highway

89, and several deer had crossed Interstate 80. The DFW is partnering with the Nevada Department of Wildlife (NDOW) to continue study and protection of the herd. In addition, the DFW and the NDOW have co-sponsored several educational programs for students at both Glenshire, California and Verdi, Nevada.

State Wildlife Areas: The CDFW operates over 21,000 acres of wildlife areas in eastern Sierra County, including Hallelujah Junction at the California/Nevada border, Antelope Valley, Smithneck Creek, and a portion of the Truckee River Wildlife Area (Places to Visit, 2022). A primary purpose of all these lands is the protection of the Loyaltan-Truckee Deer Herd winter feeding grounds, along with other species such as mountain lion, bobcat, badger, pronghorn, and raptors including golden eagle, peregrine falcon and several hawk species. Both Hallelujah Junction and Antelope Valley wildlife areas were damaged during the 2021 season's fires (CDFW Wildfires, 2021), and the USFS is assisting with the revegetation and reduction of invasive weeds.

Bordertown Wildlife Crossings Project Highway 395: In 2019, Caltrans filed a Notice of Exemption from the California Environmental Quality Act (CEQA) for a project on Interstate 395 in Lassen County and Sierra County, near the Hallelujah Junction Wildlife Area. The project will repair and improve four existing underpasses and place ~2.6 miles of new exclusionary fencing and install up to 38 new jump-outs, at a cost of \$1,000,000. (Bordertown 395, 2019).

#### **4.2 Semi-structured Interviews:**

As previously noted, detailed interviews were conducted either via “Zoom” meeting or telephone with six individuals, five of whom were involved in the project from its inception in 2002 or shortly thereafter, and one who came on-board during the Sagehen phase of the project. Five of the interview participants were motivated to enter their careers from a “love of the outdoors”, wildlife, and conservation, while the sixth came for a visit and “fell in love with the area and its people”. One of the participants is a registered Forester, while others are wildlife biologists by training. Two of the biologists volunteered that the need for habitat connectivity was gaining traction at that time, and one of them learned of this concept through studies in conservation biology at San Francisco State University in the late 1980’s.

Project Initiation: In around 2000, members of the Sierra County community contacted the Sierra County Board of Supervisors and their Fish and Game Commission to express concerns regarding the numbers of wildlife-vehicle collisions on Highway 89. Two participants observed that Sierra County was effectively “complaining” and applying “pressure” to the State and to the US Forest Service, Tahoe National Forest (TNF) to address the roadkill problem, including concerns that application of salt on the highways during winter conditions likely acted as a salt lick “magnet” for wildlife. This was not the first time that area communities voiced this concern. Decades earlier, concerns about wildlife roadkill on the newly-expanded US Route 395 at the eastern edge of Sierra County, had resulted in wildlife fencing and deer (escape) gates being erected in the 1980’s to funnel wildlife to existing bridge underpasses– in effect, some of the first WCS in this state.

Theme - Local Connections and Initiative: Connections among people from the area helped to facilitate the start of the H89ST. “Sierra County is very small - everyone knows everyone!” was one participant’s comment. This person was both a Tahoe National Forest (TNF) employee and a long-term resident of Sierra County and had taken a two-day course on wildlife crossing structures from Sandra Jacobson of the USFS Pacific Research Center. Ms. Jacobson was recognized nationally as an expert in this field at the time. The TNF employee also regularly attended Sierra County Fish & Game Commission meetings, and after hearing about the complaints of wildlife mortality on Highway 89, offered to invite Jacobson to speak with the commission about crossing structures. The Sierra County Fish & Game Commission invited representatives from the California Fish & Game Department (now the CA DFW), Caltrans, Tahoe National Forest and others to the meeting. A key Caltrans employee originally from Sierra County, was among those in attendance. Some people had to travel long distances to attend the meeting, so food was provided, and the participants got to know each other. The group agreed to meet again on a quarterly basis to devise a solution to the problem, and Jacobson was asked to serve as chair of the group now known as the Highway 89 Stewardship Team.

Meanwhile, a second local group – the “Herger-Feinstein Quincy Library Group” from the town of Quincy - had been organized to help local communities in the Feather River watershed (including portions of Lassen, Plumas and Tahoe National Forests) create a network of defensible fire breaks. According to two interview participants, this group had secured federal legislation and funding, and as a result there was significant forest thinning in the 1990s and early 2000s in the area, including on Highway 89 north of Sierraville. Members of the Quincy Library Group learned of Sierra County’s efforts to address wildlife mortality on Highway 89,

and of the Caltrans dataset for Highway 89, and wondered if thinning the trees adjacent to Highway 89 had helped reduce wildlife-vehicle collisions. As a result, members of that group attended the H89ST meetings, gained access to the Caltrans dataset, and thus became involved.

The Highway 89 Stewardship Team was an informal group, which generally met at the US Forest Service/Tahoe National Forest Sierraville District Ranger's Office. All interview participants agreed that Ms. Jacobson was the "leader" of the group, and that the team was "totally inclusive" and "self-selecting" in that anyone who wanted to, could participate. All interview participants agreed that the process was collaborative: people were respectful of each other and got along well. Some interview participants mentioned that not everyone attended regularly after the initial meetings: "the ones that were passionate about it stuck with it", according to one participant. Others said that while some team members were often not in attendance due to competing work priorities, they were on the mailing list and thus stayed informed and involved. Finally, while there was no formal organizational structure to the team, one interview participant noted that formal structure, such as a memorandum of understanding, can be advantageous for obtaining support and financing to meet their goals.

When asked if there was anyone who wasn't on the team that should have been, one person said: "At the time we had what and who we needed. Compared to now, when there is so much more momentum in this field, now we have a lot more NGO's in our group". Another responded, "Academic researcher". At least two members of the team attempted to recruit graduate students for the monitoring or other research work but were unsuccessful. When asked about whether the California Highway Patrol should have been involved due to its jurisdiction

over highway safety, one person noted that CHP representatives came to a couple of meetings, while others could not remember if they had participated at all.

Goals and priorities: Team members brought a variety of resources and priorities to the process. Sierra County contributed local matching transportation funds to the project, and the Sierra County Fish and Game Commission obtained a Title 2 education grant for rural schools from the USFS to undertake a summer program for local high school students. The California Department of Fish and Game's recruitment of the California Deer Association yielded a grant for the project as well as supportive articles in their newsletter. Caltrans managed the state highways, had access to funding, and controlled the design and construction process. Finally, the Forest Service provided "leadership and vision" through the participation of Ms. Jacobson, as well as knowledge of the forest ecosystem and the communities within it.

Theme - Education: The theme of education surfaced several times during the interview process. One participant, noted that attending the meetings could be challenging due to travel distance, but they attended because they "saw an opportunity to learn." The education program was managed by the UC Cooperative Extension participant, who hired a coordinator and worked with students on activities such as identifying animals through track plates placed in the smaller culverts and installing signage about wildlife crossing structures at the site of the Kyburz undercrossing. As the representative of Sierra County put it, "Educate the kids, and they will tell their parents!" The UC Co-op Extension representative also undertook camera trap monitoring at several points along the highway before and after the structures were installed. The CA Department Fish and Game/DFW representative brought an extensive understanding of the

Loyalton-Truckee deer herd and participated in educational activities related to the deer collar tracking project.

A priority expressed particularly by the team leader was that she wanted a project to address the needs of wildlife generally, not just deer. Many members expressed support for this concept; however, as one participant noted, there was a matter of public presentation: “Deer sells...in Sierra County. There are a lot of hunters. What are they interested in? Deer. Reducing deer mortality. And that’s what you see more – deer on the highway. And that’s what wipes out your vehicle.” Moreover, the participant explained that the concept of protecting “endangered species” was somewhat controversial for local residents since the US Forest Service had reduced logging in part due to the old-growth forest needs of the endangered Spotted Owl. This reduction in logging had resulted in a corresponding reduction of federal funding for local schools and road maintenance. Nevertheless, several smaller culverts under Highway 49 were identified for potential enlargement at a future date to accommodate smaller animals.

Another issue included the fundamental question whether installing an expensive wildlife crossing structure would actually reduce roadkill. As one participant put it, “Everyone wanted numbers. What percent of the deer herd was dying?” The team agreed that they would look at the data, to determine the best location, and that follow-up monitoring should be conducted see if it solved the problem. “We had this list of things that covered everyone’s other concerns: Caltrans/County de-icing salt on the roads...Forest Service tree cover near the roads...But again, given what we had, we had to set that aside for the time.”

Implementation - Location, Design and Funding: It was everyone’s goal to address the problem of wildlife-vehicle collisions at locations where it would be feasible to build a structure.

No other motivations for site selection were presented. A participant summarized the location decision for Kyburz as follows: “Kyburz was one of our priority areas because it had the meadow system. We knew there was a sight-distance problem...also because of the numbers of deer in that area...Also because the Little Truckee River is there...we had animals, and roadkill, and because the engineers said we could build it there for the money we had.” This sentiment was echoed by several participants. Another participant noted the practical trade-offs in topography versus animal collisions: “It wasn’t exactly where the hot spots were, but again, you can’t just look at that, you have to look at what the topography permits, so it made the most sense.” As previously mentioned, the Caltrans wildlife roadkill database which had recorded carcasses retrieved since 1979, was key to the process. In addition, although the team undertook a landscape analysis referenced earlier to narrow its choice of locations, one participant noted: “we had only met about three times, trying to figure out where to go, and [Caltrans] walked in and said: “Hey guys, I just got \$1 million for a structure, so we gotta tell them where it’s going to go!...and so we just kind of voted on Kyburz.”

With respect to the Sagehen sites, while the precise locations for structures were not selected when the team undertook initial location analysis, several participants agreed that the team wanted to “tackle” this area early on. This determination was based on the roadkill data, issues related to the road curves, camera trap information, and reports to the team by UC Berkeley Sagehen Research Station personnel that bears and mountain lions were frequently spotted in that area. The two locations were at natural gullies, so both allowed for underpasses to be installed. Another priority of the H89ST team – and its leader in particular – was to promote opportunities for research and experimentation on crossing structure features, and the proximity

of these two comparable locations created opportunities for “control” versus “experimental” structures. According to one participant, the team leader was “adamant” about this.

The choice of design and construction materials for the three structures was based on funding and topography. In the case of Kyburz Flat, the Caltrans participant explained:

“...I can only assume that the (steel pipe) culvert on Kyburz had a lot to do with the amount of fill that we had to work with, the existing landscape, flat meadow. We would have had to elevate the highway to put in a 12 by 12-foot form, so that arch culvert is not necessarily as tall as the structures at Sagehen. And you have to think of the budget. At the time, Caltrans was not used to considering projects that would benefit wildlife. So, our concrete box culverts (at Sagehen) are relatively inexpensive and easy to build – it took less than one summer to put both structures in!”

An interesting aspect of implementation turned out to be fencing. When asked why fencing was not installed at Kyburz until five years after the structure was completed, one participant responded: “The first Kyburz funding only paid for the structure. We knew that was a problem (but) we decided to take the funding and see if the deer used it without the fencing.” Although the use of different fencing types was an experimental goal of some team members, Caltrans “determined right off the bat that this was the type of fencing we needed. It’s been proven to work before.” Unfortunately, the fencing near the Sagehen structure has begun to sag, a problem that has been ascribed to heavy snow at Sagehen Pass which is wind-blown up-slope and weighs down the fencing. A USFS participant conceded: “We probably should have done a little analysis and moved that fence 100’ up the hill onto federal property.”

Yet another issue regarding the fencing came up when participants were asked whether anything should have been done differently in planning the project. Regarding communications with the public this participant noted: “We were not very transparent in our efforts, insofar as we didn’t publicize our meetings.” A second participant agreed and said that there were some

complaints about the exclusion fencing after it was erected for the Kyburz structure because it blocked access to public lands.

A maintenance issue has also arisen at the base of the Kyburz undercrossing. Seasonal flooding in the meadow has washed out 3 to 4 feet of soil over the past 13 years, and Caltrans will need to re-install substrate, which will reduce the overall height of the passageway. “So, the consideration there is ‘what is our target species?’ Mid-sized mammals have no problem. Bears don’t care about being squeezed. But it’s the deer, and the bucks with the racks that are cautious about entering enclosed structures like we have. That’s why we decided on a 10-foot wide by 12-foot-high box structure [at Sagehen], and put in 2 feet of substrate, so we end up with is ten by ten.”

Follow-up Activities: Camera trap monitoring at Kyburz Flat was undertaken for ten years by the UC Cooperative Extension. Sifting through the images and cataloging them is extremely time consuming, and a systematic analysis was not undertaken, although it is evident that several participants have seen the photos. With respect to Sagehen, while a five-year camera trap monitoring goal for the structure has been met, the Caltrans participant said: “I will still go out there – probably in April on my own time to see what is going on. I love those crossings. I know they work...”

After the structures were completed, members of the H89ST provided tours and presentations to communities across the state interested in building such structures. The CA DFW participant has met with groups in the Tule Lake area in Modoc County, the Yosemite area/Sierra National Forest, and the Mammoth Lakes/Bishop area, explaining that: “We wanted

to figure out a formula that works, and take it out to any highway. So now there are groups all over the place, and I like to think that we were part of establishing that.”

Participants were asked about other priorities for wildlife crossings or other habitat connectivity projects in Sierra County or the northern Sierra. They were asked specifically about improving the overcrossing at the Little Truckee River, north of Sagehen Pass, to improve it for use as a wildlife undercrossing. Several participants felt that this would be a good project to undertake, but that the bridge would have to be substantially retrofitted to eliminate the boulders and rip-rap currently supporting it because deer cannot walk on the boulders. However, this is not a priority for Caltrans: “I think we’ve addressed Highway 89...The priorities for us at Caltrans – the majority of them fall along Interstate 80 – the width of that highway and the herd strength.” Interstate 80, near the Nevada border at Verdi, was also an unfulfilled priority for one participant who commented: “As they enlarged Highway 80, right by the border, they put this huge concrete divider between the highway there, and the deer kill is just tremendous....I’ve seen coyotes, foxes, all kinds of animals getting killed. The deer can’t jump over the concrete divider, and if they do make it over the traffic is bumper to bumper... People going to or coming from Reno.”

Other participants spoke about a planned Caltrans road-straightening project on Highway 20 in nearby Nevada County. Caltrans needed the USFS to grant a right-of-way easement for the project, and the Forest Service is requiring a wildlife undercrossing as a condition of approval due to a high number of reported animal collisions. Caltrans has agreed, and two crossing structures are now planned there. One participant felt that this successful outcome was a direct result of earlier US Forest Service experiences in which crossing structures were planned, but

ultimately cut from the final project due to cost overruns and because they were not required as a condition of the easement. The California DFW participant also credited Caltrans environmental staff's involvement in the Highway 89 Stewardship Team for bringing wildlife connectivity to the forefront of Caltrans' thinking, and discussed the increased level of coordination between state agencies:

“Caltrans came to us (for the Highway 20 project) and said ‘we’re doing this project and plan to put these structures in with fencing and jump outs’ – and I went and looked at the site, and it is good. So, I went to the biologist that is in that area and told him about the plan and said that he shouldn’t ask Caltrans to mitigate for the project, because the mitigation is already in the plans... This is a revolution, in that staff has had to come together in ways that they haven’t had to before.”

When asked about other projects being undertaken in California, the DFW participant talked about projects along Interstate 395 in Mono County and in San Bernardino County in Southern California. The Caltrans participant cited three overcrossings planned on Highway 1 near Arcata and other areas as evidence that wildlife crossing structures are catching on:

“...as progressive as we Californians think we are, we are behind the rest of the world on this, so just having these three (overcrossings) in the queue is a huge success for us. And of course, the [highly publicized overcrossing] project down at Liberty Canyon [Highway 101 in Los Angeles] has paved the way for all this.”

When asked about the significant state and federal funding that has been recently approved for wildlife crossing structures, the Caltrans participant replied: “Yes. That’s where the environmental biologists and stewards like the ones we are working with are drooling at the mouth on that, and it also says that this is now being recognized as a major issue, and we’re deciding to do something about it.”

A final project that the interview participants were asked about was the planned “Bordertown” undercrossing upgrade project on Highway 395. When asked whether the team is involved in that, one participant said: “My successor has determined that there are other priorities. Mostly wildfire – the same thing I was doing for most of my career”. Another said: “Any [H89ST] members that want to stay involved can attend the meetings. They don’t meet as often, and I missed the last meeting...” When asked whether local governments representatives were invited, another participant said: “I don’t really know, we kind of gave it over to Wildlands...” The Wildlands Network, an NGO which has managed other such projects, has a network of organizations that can contribute resources, including funding, to the Bordertown project, and now is the “organizational lead” for that project. The Sierra County participant explained, “When [the Highway 89 project] was finished, we felt that our involvement has been done, so if anything new will be done, we need to start from scratch”.

Theme - Succession and Institutionalization: Of the original members of the H89ST, three of the six I interviewed have retired or are planning to retire in the near future. This confirms what Ms. Jacobson identified as one of the future challenges for the H89ST: “succession”. In fact, it appears that the H89ST has essentially disbanded. As discussed above, it also appears that the process for considering and installing wildlife crossing structures is becoming more institutionalized as part of the Caltrans project environmental review and mitigation process and the experience gained from the Highway 89 project seems to have played a part in that. Also, the significant state and federal funding recently approved for these structures will allow Caltrans to consider installing more of these structures where needed.

Theme - Wildfire Effects on Wildlife: One of the final questions asked of the interview participants was whether the recent wildfires in the Sierras had altered their perspective of what is needed to protect wildlife in the area. One participant said: “I can’t help but think that when you have all of these fires, you are losing forage and cover habitat – all these things that the animals need to successfully move in their migration routes.” The CDFW participant agreed:

“The deer are highly fidelic, so even after a wildfire they prefer to go back to the area that they are familiar with: ‘back on the black’. ...It’s different on the east side (of the Sierra) than on the west. If fire happens on the west side where there is heavy forest cover...fire is great because it sets up the area for succession growth and forage...But if it happens on the east side in winter range, and the fire consumes all the sage and bitter brush, then it is devastating. With fire after fire out there, we have to continue to monitor those existing underpasses to see if they’re still being used...Connectivity is even more important if the deer have to jet through the area to get on the other side of the highway where it’s not burned. Fire is complex, and you have to be adaptive with it.”

The Caltrans participant agreed that due to the wildfires and climate change there is a value in continuing to monitor the numbers and array of wildlife using the crossing structures.

Forest Service participants had even more to say about wildfires:

“...Burnt forests are what we’re going to see in our future’. The Forest Service doesn’t ‘treat’ acres. We analyze them and put them out for bid or contract. About 90 to 95% of the acres in the Sierras cannot be underburned. They would just go into a wildfire. Pre-treatment involves someone going in and cutting the little trees and underbrush down and pushing them into piles...masticating it with machinery. So we change the forest from 700 trees per acre down to 105 or 110...But the machinery and personnel involved in doing that – we just don’t have that in this state. The biggest problem is where to take the material.”

The Sierra County participant also noted that there is currently an inability to fill open positions in the County as well as the USFS, in part due to lower wages in the area, but also due to a lack of available, affordable housing, and emphatically stated that the forest fire prevention and tree thinning efforts are necessary not only to protect residents, but wildlife too.

Adaptive Co-management: The concept of adaptive co-management was briefly explained to the interview participants, and they were asked if they thought it applied to this project. They all felt the collaborative aspect of this concept applied. As one participant put it: “The collaborative part – that is what drove this project, in that none of the agencies could take responsibility and make something happen on their own. It was really about pulling resources from each of the different groups which made the project successful. Money, time, experience, no one had it all.” And: “we all learned from one another. And you don’t all have the same values – everyone is coming from a different perspective, and different interests...these groups are potentially very conflict-ridden, but I learned so much from that: how to be diplomatic, how to explain issues to people, and to provide information...People trusted what we were doing.”

With regard to the adaptive aspect of the project, the response was more nuanced:

“It was always our goal to try something, see how it worked, adapt if needed, figure out what worked best, and produce almost a manual for this process. While we don’t have a written manual, this process has been replicated all over the state. We didn’t get to do as much of the experimentation as we wanted. We wanted to get the highway designated as an experimental highway where we could try different techniques. That didn’t work out because of limitations from the engineers, maintaining safety on the highway, and then a lot of it too was just not having enough money.”

And more with regard to the “adaptive” aspects of the project: “...Yes and no. Once we decided to put in a structure you can’t just say ‘ah, that didn’t work there, let’s move it over here’. But when you talk about adaptation looking at the bigger scale there is adaptation. Look at what was done elsewhere and adapt it for use here.”

#### **4.3 Monitoring Data Results:**

Caltrans Carcass Data: As previously discussed, wildlife carcass collection data has been collected for Highway 89 for over 40 years, and thus provides a valuable source of information

about where wildlife-vehicle collisions have occurred. Due to a variety of factors, including weather and the actions of predators, the dataset is not considered to be scientifically valid and is likely an undercount of wildlife-vehicle collisions. The data distinguishes between deer (bucks, does, fawns), and “unknown” other species, which account for very little of the data. The data are for the first 15 miles of Highway 89 within Sierra County (south to north). Sierraville is located at roughly the 15-post mile marker. While the data collection began in 1979, that year has been eliminated from this presentation to provide a direct comparison between four decades of wildlife-vehicle collision data. Table 3 below shows that the areas around the Sagehen and Kyburz Flat crossing structures had relatively high numbers of wildlife-vehicle collisions, but that there are several other areas that are similarly high including post-miles 9 and 13.

**Table 3. Hwy 89 Carcass Data by Post Mile, 1980 - 2019**

Sierra County Post Miles	Carcass Count	Sierra County Post Miles	Carcass Count	Sierra County Post Miles	Carcass Count
PM 0 - .5	44	PM 5 – 5.5	49	PM 10 – 10.5	22
<b>PM .5 - 1</b>	<b>42</b>	PM 5.5 - 6	26	PM 10.5 - 11	18
<b>PM 1 - 1.5</b>	<b>40</b>	PM 6 – 6.5	37	PM 11 - 11.5	12
PM 1.5 - 2	43	PM 6.5 - 7	12	PM 11.5 - 12	21
PM 2 - 2.5	59	PM 7 – 7.5	18	PM 12 – 12.5	13
PM 2.5 - 3	26	PM 7.5 - 8	6	PM 12.5 - 13	38
PM 3 - 3.5	23	PM 8 – 8.5	26	PM 13 – 13.5	58
PM 3.5 - 4	21	PM 8.5 - 9	23	PM 13.5 - 14	44
PM 4 – 4.5	60	PM 9 – 9.5	50	PM 14 – 14.5	38
<b>PM 4.5 - 5</b>	<b>32</b>	PM 9.5 - 10	14	PM 14.5 - 15	18
<b>Total carcasses: 933: 62.2 carcass per mile over 40 years or 1.55/mile/year</b>					

*Table 3. Sagehen South crossing structure is located at PM .8, Sagehen North crossing structure is located at PM 1.4 and Kyburz Flat crossing structure is located at 4.977. Source: Caltrans TASAS wildlife carcass data for Hwy 89 (2021).*

Table 4. below shows that, overall wildlife-vehicle collisions have dropped significantly over the past four decades, including a ~71% drop during the 2010-2019 period.

**Table 4. Hwy 89, Sierra County Carcass Data Post-Mile 1 – 15 by Decade: 1980 - 2019**

<b>Year 1980's</b>	<b>Carcasses</b>	<b>Year 1990's</b>	<b>Carcasses</b>	<b>Year 2000's</b>	<b>Carcasses</b>	<b>Year 2010's</b>	<b>Carcasses</b>
1980	23	1990	70	2000	35	2010	3
1981	19	1991	40	2001	0	2011	15
1982	18	1992	56	2002	18	2012	6
1983	44	1993	20	2003	30	2013	7
1984	52	1994	13	2004	28	2014	3
1985	19	1995	13	2005	31	2015	12
1986	50	1996	11	2006	35	2016	2
1987	59	1997	22	2007	24	2017	1
1988	36	1998	23	2008	3	2018	9
1989	48	1999	18	2009	12	2019	5
<b>Totals</b>	<b>368</b>		<b>286</b>		<b>216</b>		<b>63</b>
	<b>2.45/mile/yr</b>		<b>1.91/mile/yr</b>		<b>1.44/mile/yr</b>		<b>0.42/mile/yr</b>
	<b>% Reduction from previous decade</b>		<b>-22.3%</b>		<b>-24.5%</b>		<b>-70.8%</b>

*Table 4. Source: Caltrans TASAS wildlife carcass data for Hwy 89 (2021).*

Tables 5 and 6 below compares carcass collection data for a one-mile area surrounding each structures, including the exclusion fencing, and a half-mile zone beyond during the 10-years prior to installation of the wildlife crossing structures, and the 10-years following construction. In the Kyburz Area, including post-miles 4-6, 53 carcasses were collected pre-construction, an average of 2.65 per year per mile. The number of carcasses in this two-mile area dropped by 94% in the five years following the installation of the structure, and two of the three carcasses were located within the area to be fenced. The number of carcasses increased to seven during the six years after the fencing was installed in 2013. None of these seven carcasses were within the

fenced area, but they were within a half-mile zone outside the fence ends at SIE: 4.0, 4.0, 4.21, 4.3, 5.73, 5.8, and 5.8. As discussed in the Literature, wildlife collisions tend to increase just outside the fenced areas, particularly when the fencing is less than three miles in length.

For the Sagehen Area, from post miles .25-2.25, the number of carcasses was lower to begin with but dropped by 83% after construction. One of the three carcasses collected after the structure and fencing was installed was within the fenced area at post mile .78, while the other two were located within approximately one-half mile of the north fence end.

**Table 5. Carcass Data – Before/After Kyburz Crossing Structure**

<b>Post Miles</b>	<b>Pre-Construction 1998-2007</b>	<b>Construction Year 2008</b>	<b>Pre-Fence Installation 2009-2012</b>	<b>Post-Fence 2013-2019</b>
4 - 4.5	22		1	4
4.5 - 5	13		1	
5 - 5.5	11	1	1	
5.5 - 6	7			3
<b>Total</b>	<b>53</b>	<b>1</b>	<b>3</b>	<b>7</b>

*Table 5. Kyburz wildlife crossing structure is located at ~ Post Mile 4.98. South Fence end is at PM 4.45 and North Fence end is at PM 5.54. Source: Caltrans TASAS wildlife carcass data for Hwy 89 (2021).*

**Table 6. Carcass Data – Before/After Sagehen Crossing Structures**

<b>Post Miles</b>	<b>Pre-Construction 2006- 2015</b>	<b>Construction Year 2016</b>	<b>Post Construction 2017-2019</b>
.25 - .75	2		
.75 – 1.25	6		1
1.25 – 1.75	4		
1.75 – 2.25	5	1	2
<b>Total</b>	<b>17</b>	<b>1</b>	<b>3</b>

*Table 6. Sagehen South is located at PM .8 and Sagehen North is located at PM 1.4. The South fence end is located at PM .62 and the North fence end is at PM 1.81. Source: Caltrans TASAS wildlife carcass data for Hwy 89 (2021).*

**Table 7. “Control Areas” Carcass Data**

<b>Control Area PM 2.5 – 3.5</b>		<b>Control Area PM 6.5 – 8.5</b>	
1998-2007	10	15	
2008-2013	3	3	
2014-2019	2	1	
<b>Total</b>	<b>15</b>	<b>19</b>	

*Table 7. Source: Caltrans TASAS wildlife carcass data for Hwy 89 (2021).*

Table 7. above provides a comparison between the Kyburz and Sagehen Areas, and nearby portions of Hwy 89 for the dates before and after installation of the crossing structures. The one-mile area SIE 2.5-3.5 lies between the Sagehen North and the Kyburz Area fence ends. SIE 6.5-8.5 is a two-mile area north of the Kyburz crossing structure area and lies approximately one mile away from the Kyburz Area north fence end. In short, the rate of carcass collections is similar for both control areas and shows a similar drop-off in collisions over the period, although there is a steeper drop-off in collisions in the Kyburz Area, where carcass collections were much more numerous in the early 2000s. The reduction in carcasses over the 20-year period was 80% from SIE 2.5-3.5 and 93% for SIE 6.5-8.5.

Camera Trap Data: Motion-sensor camera images were obtained for both the Kyburz structure and for the Sagehen structures, to determine the number and variety of species visiting the structures, and the “passage rate” of the animals through the structures. While cameras were placed in many locations along the highway, this analysis primarily concerns the cameras located on either side of the crossing structures after they were built. As with the carcass data, it is important to note the limitations of the camera trap data. One limitation is that the days of monitoring vary from year to year from 84 days in 2016 to 292 days in 2015 in the case of Kyburz. One reason for the variance is that the length of the winter season affected the

monitoring activity, both for operation of the cameras and the photo capture of animals. The crossing structures are in summer season grounds for the migrating deer herd, so deer are not generally present during the winter months, and other animals such as bear are likely to be in hibernation. However, the variation in the number of photo monitoring days per year makes it difficult to compare annual variation in animals passing through the structures. Another limitation of this data is that cameras sometimes malfunctioned and produced no photos for months or even a whole year. As a result, the passage of animals from one side to the other was not always documented.

Because of the limitations outlined above, an effort was made to interpret the activity and position of the animals captured on camera. Deer were determined to have passed through a structure if they were identified through hide markings or antlers by camera photos on both sides of the structure. Most animals passing were identified this way. However, if no matching camera photo was available, animals would be considered as passing through if one camera showed them at the entrance or within the structure and moving “with intent” straight through. At Kyburz, the deer often visited the structure to browse. Other times, deer would be captured standing at the underpass entrance and looking into the passage with curiosity or hesitation – and these photos were not counted as passage. For all structures, the “duplicate” photos indicate extra pictures of animals that are already documented. At the Sagehen Pass structures, deer did not visit and “hang out” as they do at Kyburz, but instead seemed to use game trails on either side of the highway, and thus were identified as passing by the structures, rather than into or out of them. As a result of this level of interpretation, the results of the camera trap data analysis

cannot be considered scientifically valid. However, the following results can give some sense of the usage of the structures.

**Figure 13. Deer Passage at Kyburz Flat Wildlife Crossing Structure**



*Figure 12: Top: Buck Passage west to east: photo # 226-00143, 8/3/2016, 5:11 am., photo # 227-00138, 5:13 am. Bottom left: Doe browsing photo # 226-00145, 6/15/2015, 4:31 am . Bottom right: Buck looking into the crossing structure (no passage). Photo # 227-0067, 6/26/2013, 1:37 am. Source: Kyburz Crossing Structure Camera Trap data (2021).*

**Table 8. Kyburz Flat Wildlife Crossing Structure Camera Trap Data: 2009-2018**

Year	Photo Dates	Photo Days	Deer	Other Animals	Total Animals	Passage	Rate %	Duplicates
2009	6/25 – 11/4/2009	133	45	1	46	30	66.7	115
2010	5/18 - 11/2/2010	169	51		51	37	72.6	31
2011	5/16 – 11/23/2011	192	48		48	32	66.7	32
2012	4/24 – 12/7/2012	228	71	1	72	39	54.2	84
2013	4/1 – 11/7/2013	221	157		157	98	62.4	271
2014	3/26 – 12/23/2014	273	153	2	155	120	77.4	425
2015	3/6 – 12/22/2015	292	309	18	327	219	67.0	365
2016	6/30 – 9/21/2016	84	145	9	154	104	67.5	100
2017	6/21 – 11/29/2017	162	158	22	180	99	55.0	76
2018	6/26 – 10/30/2018	127	50	20	70	43	61.4	93
<b>Total</b>		<b>1,881</b>	<b>1,187</b>	<b>73</b>	<b>1260</b>	<b>821</b>	<b>65.1</b>	<b>1592</b>

Table 8. Source: Kyburz Crossing Structure Camera Trap data (2021).

**Table 9. Kyburz Flat Wildlife Crossing Structure Camera Trap Data 2009 – 2018: Detail of ‘Other Animals’**

Year	Birds	Coyotes	Bobcats	Black Bears	Total
2009-14	3	1			4
2015		7	11		18
2016	1	7	1		9
2017	1	16	5		22
2018		17		3	20
<b>Total</b>	<b>5</b>	<b>48</b>	<b>17</b>	<b>3</b>	<b>73</b>

Table 9. Source: Kyburz Crossing Structure Camera Trap data (2021).

Camera trap data for the Kyburz crossing structure shows a total of 1,260 animals – 94% of them deer – visited the structure during the 10 years of monitoring. The overall passage rate during the 10 years of monitoring was 65%, which is at the lower end of other studies which found that successful passage through underpasses ranged from 64%-86% by year four (Simpson, N.O et al. 2016). Again, this may be attributed partly to the fact that this structure is

in a location where the deer range during the summer months. However, it may be that the flat terrain around Kyburz, gives the animals more opportunities to cross the highway north or south of the fence ends. The first four years that the Kyburz structure was in place had relatively few animal visits, although the passage *rates* are actually similar to later years, and higher than expected based on the literature.

Tables 10 and 11 show that the Sagehen structures had lower overall visitation rates than at Kyburz during the years monitored, which may be attributable to the location of Kyburz adjacent to the meadow and riparian area, versus the Sagehen Pass mountainside locations, where deer have no opportunity to congregate. The Sagehen structures also had somewhat lower overall passage rates than Kyburz, even comparing the first five years' passage rate of 63% at Kyburz to the rates of 62% and ~ 53% passage rates at Sagehen South and North.

**Table 10. Sagehen South Wildlife Crossing Structure Camera Trap Data:  
2016-2020**

<b>Year</b>	<b>Photo Dates</b>	<b>Photo Days</b>	<b>Deer</b>	<b>Other Animals</b>	<b>Total Animals</b>	<b>Passage</b>	<b>Rate %</b>	<b>Duplicates</b>
2016	10/7 – 10/9/2016	2	4		4	4	100	4
2017	5/24 – 11/4/2017	166	7	17	24	13	54.2	34
2018	5/19–11/26/2018	191	5	17	22	12	54.6	16
2019	6/4 – 11/13/2019	162	9	14	23	11	47.8	27
2020	5/4 – 11/25/2019	205	3	24	27	22	81.5	13
<b>Total</b>		<b>726</b>	<b>28</b>	<b>72</b>	<b>100</b>	<b>62</b>	<b>62.0</b>	<b>94</b>

*Tables 10. Source: Sagehen Crossing Structures Camera Trap data (2021) .*

**Table 11. Sagehen North Wildlife Crossing Structure Camera Trap Data:  
2016-2020**

<b>Year</b>	<b>Photo Dates</b>	<b>Photo Days</b>	<b>Deer</b>	<b>Other Animals</b>	<b>Total Animals</b>	<b>Passage</b>	<b>Rate %</b>	<b>Duplicates</b>
2016	10/9–11/20/2016	43	3	2	5	3	60.0	2
2017	5/27-11/11/2017	168	73	12	85	47	55.3	68
2018	5/19-10/29/2018	164	18	6	24	11	45.8	67
2019	5/24-11/22/2019	172	100	22	122	65	53.3	225
2020	5/6-12/3/2020	181	52	22	74	38	51.4	88
<b>Total</b>		<b>728</b>	<b>246</b>	<b>64</b>	<b>310</b>	<b>164</b>	<b>52.9</b>	<b>450</b>

*Tables 10. Source: Sagehen Crossing Structures Camera Trap data (2021) .*

Perhaps the most interesting aspect of the Sagehen wildlife crossings is the number and variety of ‘other animals that passed by or through the structures. At Sagehen South, 72% of all animals photographed were species other than deer, compared with 21% at Sagehen North, and 6% at Kyburz. In comparing these percentages with the carcass collection data for the two-mile area surrounding the crossing structures over the 40-year period, the Kyburz ‘other animal’ (UNK) carcasses was 13, or 7% of the total, which is similar to the percentage of ‘other animals’ recorded by camera. However, for the Sagehen area, the TASAS data for post-miles .25-2.25 recorded 11% of the carcasses as “UNK”/other animals”, a much lower percentage than the camera data for the Sagehen South crossing structure.

Finally, camera data from north fence end locations and several jump-out locations show that animals were finding the fence ends at the north end of the Sagehen Pass structures and were also able to use the jump-outs. The number of animals visiting the fence-ends may also help explain the increase in wildlife-vehicle collisions just beyond the fence-ends.

**Table 12. Sagehen South & North Wildlife Crossing Structure Camera Trap Data  
2016 – 2020: Detail of ‘Other Animals’**

<b>Sagehen South &amp; North WCS Camera Trap Data: ‘Other Animals’</b>						
<b>Sagehen South WCS Camera trap Photos</b>						
<b>Year</b>	<b>Coyotes</b>	<b>Bobcats</b>	<b>Black Bears</b>	<b>Mtn. Lions</b>	<b>Other</b>	<b>Total</b>
2016	0	0	0	0	0	0
2017	1	7	4	0	5	17
2018	1	15	1	0	0	17
2019	5	3	6	0	0	14
2020	11	6	7	0	0	24
<b>Total</b>	<b>18</b>	<b>31</b>	<b>18</b>	<b>0</b>	<b>5</b>	<b>72</b>
<b>Sagehen North WCS Camera Traps Photos</b>						
<b>Year</b>	<b>Coyotes</b>	<b>Bobcats</b>	<b>Black Bears</b>	<b>Mtn. Lions</b>	<b>Other</b>	<b>Total</b>
2016	1	0	1	0	0	2
2017	2	0	9	0	1	12
2018	2	2	1	1	0	6
2019	6	1	9	2	4	22
2020	9	3	5	1	4	22
<b>Total</b>	<b>20</b>	<b>6</b>	<b>25</b>	<b>4</b>	<b>9</b>	<b>64</b>

*Table 11. Source: Sagehen Crossing Structures Camera Trap data (2021)*

**Table 13. Sagehen Camera Trap Data at Fence ends and Jump-outs**

<b>All Years 2017 2020</b>	<b>Deer</b>	<b>Other Animals</b>	<b>Total</b>	<b>Comments</b>
Cam 278 NW Fence End	107	22	129	
Cam 279 NE Fend End	102	29	131	
Cam 280 W-side Midpt. Jump-out	2	10	12	3 jumps
Cam 281 E-side Midpt. Jump-out	184	43	227	No jumps
Cam 282 NW-side Jump-out	43	7	50	8 jumps
Cam 283 NE side Jump-out	18	25	43	1 jump up (bobcat)
<b>Total</b>	<b>456</b>	<b>136</b>	<b>592</b>	

*Table 22. Source: Sagehen Crossing Structures Camera Trap data (2021).*

**Figure 14. Wildlife Use of Sagehen Structures, Fence Ends, and "Jump-outs"**



*Figure 22. Top Left: Sagehen North Structure Mountain Lion, File 11/33/2016, 274-1-00065 11/1/2019 4:29 am; Top Right: Bear at N.E. Fence end, File 11/22/2018 279-1-00024 10/27/2019 3:11 am; Bottom Left: Deer at NW Sagehen North Jump-out, File 9/4/2018, 282-1-00026 June 3, 2018 5:20 am; Bottom Right: Three deer inside fence at Sagehen North, west side, File 7/31/2020, 277-1\_00022 May 6, 2020 4:31 am. Source: Sagehen Crossing Structures Camera Trap data (2021).*

## **Discussion**

### **5.1 Archive Research Comparison with Interviews:**

The archival literature and interview results mostly tell a consistent story about project initiation, leadership, collaborative decision-making and funding sources. One discrepancy worth noting is that archival information indicates that the fencing at Kyburz was funded in a “second grant” in 2008 but was not built until 2013 (DFG, Loyalton-Truckee Deer Herd). This discrepancy was not clarified in the interviews, except to say that it was a funding issue. The archival information was very useful in that this process began approximately 20 years ago, and participants cannot be expected to remember and convey all details about the project.

### **5.2 Adaptive Co-management: Comparison of Interviews with Literature:**

All six interview participants confirmed the premise that the Highway 89 Stewardship Team efforts was a collaborative effort and that this was key to the success of the project. In addition, participants noted the project’s success in that wildlife-vehicle collisions have declined, that the camera images show the structures being used, and that other crossing structures in the region are now being planned. The interview process recalled a statement by Plummer (2009) that “rights and responsibilities should be shared among those with a claim to the environment of a natural resource” (Plummer, 2009), and that the co-management process includes the three stages of independence, association, and integration. In the first stage three state and federal agencies – Caltrans, California Department of Fish and Wildlife, and the US Forest Service – were each doing their own projects, such as maintaining and expanding wildlife preserves in the area, monitoring wildlife roadkill on Highway 89, and undertaking research and promoting

efforts to maintain forest health and protect endangered species - while local residents were observing the high degree of roadkill on Highway 89. The Association phase came about after Sierra County reached out to voice concern over the roadkill, and a locally connected resident working for the USFS heard about the concern and offered to bring about the discussion regarding wildlife crossing structures, and others such as the Quincy Library Group also became involved.

Participants expressed some regret that the goals of including existing smaller culvert adaptations, experimentation on crossing structure features, and the post-completion evaluation were not achieved at the time. As stated in the Literature Review: “In natural resources adaptive management simply refers to a structured process of learning by doing and adapting based on what’s learned (Walters and Holling, 1990)” (Williams, B.K. 2011). In reviewing Williams’ ‘six step’ iterative process, the H89ST undertook steps one through four, but did not complete steps five and six: “evaluating”, and “adjusting and trying new solutions”. However, a substantial amount of monitoring data was gathered and was used in this analysis. Moreover, other research - particularly the Loyalton-Truckee Deer Collar study – has emerged from this project. And as one participant noted: “The (Sagehen) structures are still there”, meaning that future research could still be undertaken on the paired structures. Finally, several participants commented on the fact that the process was adaptive in a larger sense because the team drew from the experience of other wildlife crossing structure projects through Sandra Jacobson, and that team members subsequently disseminated information about the H89ST process and the crossing structures via articles and presentations to other interested parties.

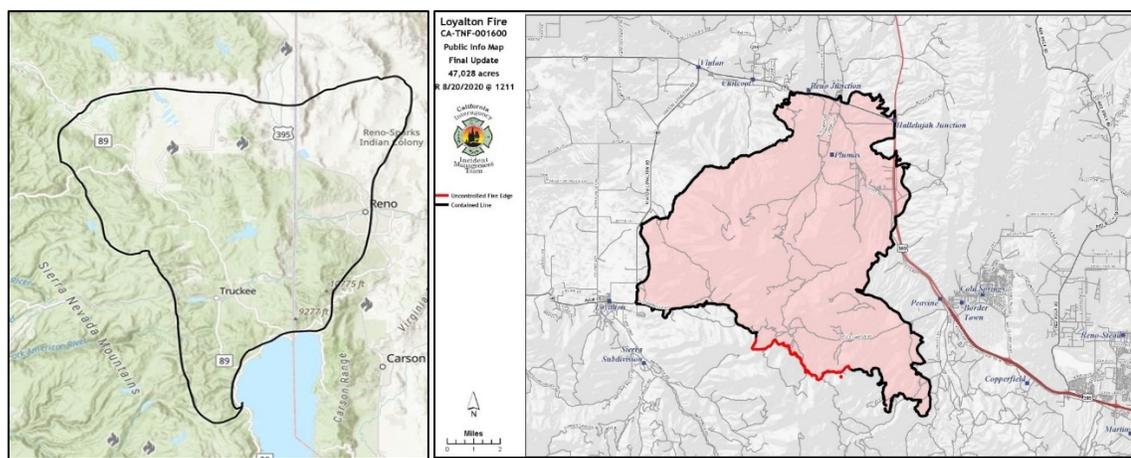
Interview Themes: As previously noted, the theme of Local Connections and Initiative can be compared to Plummer's first two stages of collaborative management, which are Independence and Association. The Integration phase happened after the H89ST met, determined its goals, and identified priority locations, and Caltrans – prompted by a Caltrans staff person who had lived and worked in the area - funded the projects. The ties between state, federal and local government personnel, as well as input from local individuals were key in bringing attention to the problems and facilitating the formation of the H89ST. This goes to the statement by Clevenger and Ament (2017) and Ament (2018) that many such agencies need to collaborate where their missions overlap, and to share information in order to determine priorities and information gaps. The theme of Education has also been discussed. Not only were the education programs useful in gaining the approval of Sierra County residents, but undertaking this project contributed to knowledge about and support for undertaking such projects in other parts of the state. The education theme echoes another recommendation by Ament (2018), that education and outreach are important to the process of developing wildlife crossing structures, as well as the comment by Armitage (2008) that learning and collaboration are essential to the adaptive co-management process.

The theme of Succession and Institutionalization was not addressed in the literature, with the exception that succession planning was noted as a problem by Jacobson in the archival search. Capital projects - especially novel ones such as these wildlife crossings were in 2002 - often require several years to plan, fund, and undertake; the fact that some members of the team retired or moved onto other work is not surprising. In the case of Ms. Jacobson's retirement it appears that other team members as well as The Wildlands Network NGO have filled in for part

of her role for successor projects such as the Bordertown improvements. The use of NGO's may become the norm, given government funding and staffing limitations. Also, as wildlife crossing structure placement and other solutions to wildlife-vehicle conflict become more familiar, agencies such as Caltrans will more routinely consider them as part of the environmental mitigation process. As funding increase for such projects, one problem that will become more evident is how to prioritize the installation of crossing structures.

Regarding the theme of Wildfires and climate change effects, the topic was not a focus of this thesis, but it is useful to note that 2020 had the greatest number of wildfires in California recorded history, with a total of almost 4.4 million acres burned in the state. Both the Loyaltown Fire (47,029 acres) and the Antelope Fire (102 acres) were located within Sierra County, while the North Complex fire (318,935 acres) was located in adjacent Plumas and Butte counties, and the Poeyville Fire (2,975 acres) was located along Interstate 395 at Truckee Meadows in Nevada. The Sierra County fires caused damage to the winter range of the deer herd in Sierra Valley, notably at the Antelope Wildlife Preserve (Fire, 2020). In 2021 there were more major fires, including the Beckwourth Complex (105,670 acres) and the Dixie fire (963,309 acres), both located in neighboring Plumas and Lassen counties (Fire, 2021). This really is the issue of the age in the Sierra Nevada, and as participants noted, it affects wildlife as well as human habitats and exacerbates the need for wildlife mobility across highway corridors.

**Figure 15. 2020 Wildfires Affecting Loyalton-Truckee Deer Herd Range**



*Figure 15. Left: Wildfires Affecting Loyalton Truckee Deer Herd Range. Source: Fire (2020) With outline of the Loyalton-Truckee Deer Herd Range sketched by author. Right: Extent of the 2020 Loyalton Fire, in the northeastern portion of the Loyalton-Truckee Deer Herd Range. Source: Loyalton Fire Information (2022).*

### 5.3 Monitoring Data Comparison with Literature:

Caltrans Carcass Data: The UC Davis Road Ecology Center/California Roadkill Observation System (CROS) and the Caltrans Traffic Accident Surveillance and Analysis System (TASAS) carcass data both show a decline of wildlife-vehicle collisions from 2010 through 2019 along Highway 89, although the CROS data showed a much higher density of roadkill than did the Caltrans data for the first half of that decade. It appears that Highway 49 - which intersects Highway 89 at the northern edge of Sierra County - continues to experience 2-4 large mammal collisions per mile per year.

The Bissonette (2007) study, which used the Caltrans TASAS data for the full length of Highway 89 in Sierra County and found ~1 carcass/mile/year from 1979 – 2005 does not match this thesis’s findings of ~1.55 carcass/mile/year from 1980 – 2019 for the southern 15 miles in Sierra County. Since the same dataset was used for both studies, the logical conclusion is that there was a higher frequency of wildlife-vehicle collisions on the southern portion of Highway

89 in the County. This affirms the choice of the H89ST to concentrate its efforts in the southern half of the County.

Analysis of the Caltrans TASAS carcass data showed that while collisions are virtually non-existent within the fenced areas, there have been some collisions just beyond the fence ends, particularly at Kyburz Flat. This is consistent with the findings of Huisjer et. al (2016), which found that exclusion fencing which extends for less than five kilometers (three miles) have increased wildlife collisions at the fence ends. This study also recommends that natural barriers (such as the Little Truckee River), are a good place to terminate exclusion fencing, and that curving the fencing away from the road at the ends may also help direct wildlife away from the road.

As previously mentioned, it is puzzling why wildlife collisions have fallen so much along the entire southern 15 miles of Highway 89 in Sierra County since 1990 – even well beyond the range of the crossing structures. One interview participant recalled discussing this question with colleagues during the H89ST planning process in around 2003 and came up with several possibilities for the lower collision numbers, including tree thinning alongside the highway, a very severe winter in 1992-93 that may have caused a high rate of animal mortality, or a possible increase in the mountain lion population due to their increased protection status.

This question was posed to the Caltrans and Department of Fish & Wildlife in a follow-up email. One responded that they had noticed fewer images of deer moving through the Sagehen structures last year (2021) than previously and suggested that recent fire activity within the Loyalton-Truckee deer herd's range has had an impact on where and when the deer move. The other participant agreed and noted that fires have had a definite impact on the forage

availability in their historic winter range, including Hallelujah Junction (near Bordertown and Interstate 395) which has “almost no cover on it”. The participants are part of another multi-agency effort – including the Nevada Department of Transportation - along Interstate 395 (Bordertown) where cameras are documenting deer herd movement, and they hope to capture some of these changes. The DFW participant also indicated that the agency is starting a 10-year herd monitoring plan, which they hope will answer some of these questions. With just a few GPS collars currently deployed, the DFW has noticed that the deer are tending to migrate north-to-south rather than their usual west-to-east migration path, and may be limiting their migrations due to lack of forage.

Another phenomenon mentioned is that while survival rate appears to remain relatively high in adult does, the fawn/yearling “recruitment” rate is low. The DFW participant mentioned that the predator population is very high right now, and that bears kill many fawns, and compete for deer kill with mountain lions. Indeed, according to the CA Department of Fish & Game website, the California bear population has risen from ~10-15,000 in 1982 to ~30-40,000 in recent years (Bear Population, 2020).

Camera Trap Monitoring Data: The camera trap data for the three structures can be compared in terms of total number of animals, passage rates, and the types of animals documented. The Kyburz structure was monitored for ten years, and the Sagehen structures for 5 years. Kyburz Flat cameras documented more animals at the structure – even in the first five years (374) than either Sagehen South (100) or Sagehen North (310). The passage rate through the Kyburz structure (64.5% for the first five years) was also somewhat higher than at Sagehen South (62%) or Sagehen North (53%). Passage rates documented for all three structures

remained at about the same level, even as the numbers of animals visiting the structures increased over the years. It appears that the animals did not require much time to acclimate to the structures, as discussed in the literature. Overall, passage rates for the three structures were at the lower end of “normal” based on the aforementioned Nevada and Arizona studies (Simpson et al., 2016 and Gagnon et al., 2011). However, it must be reiterated that the techniques used in this thesis to determine successful passage rate are not necessarily the same as those used in other studies.

Finally, as previously noted, the ratio of deer to other animals varied between structures. At Kyburz Flat, ~94% of the animals documented were mule deer, versus 79% at Sagehen North, and only 28% at Sagehen South. Coyotes were the most common species other than deer at Kyburz, while black bears were the most common other species at the Sagehen structures. While it is tempting to focus on the high percentage and variety of ‘other animals’ at the Sagehen structures, the more significant difference is in the numbers of deer visiting each structure, particularly at Sagehen South. Updated information about the deer herd is needed to determine whether migration routes have changed, or the population overall has declined.

## Conclusions

The Highway 89 Stewardship Team's effort to bring wildlife crossing structures to Sierra County was very successful as a collaborative endeavor and has also resulted in at least two additional projects – the Loyalton-Truckee Deer study and the Interstate 395/Bordertown wildlife crossing improvements. The project has also helped inform the planning of a wildlife crossing project on Highway 20, and other parts of California. Several themes were developed from the interviews, including one which is that education of the public and the institutions involved was an important outcome of this project. Additionally, as the public becomes more aware of the need for wildlife habitat connectivity, and as more funding is available, the planning and construction of WCS is increasing and becoming more “institutionalized”.

The H89ST had ambitious goals to monitor, experiment with, and adapt the structures in various ways. While these goals were only partially realized, the monitoring data has been used in this thesis. The Caltrans carcass data shows that wildlife mortality on the southern 15 miles of Highway 89 in Sierra County has dropped dramatically in the last several decades, although there is still mortality at the project fence ends. One recommendation that has been discussed is to extend the exclusion fencing surrounding the structures to achieve a total of ~ three miles of fencing at both Kyburz and Sagehen. In addition, continued monitoring of the structures and the deer herd collar study is essential to determine what is happening to the deer herd population, as recent fires and other ecosystem changes may be impacting the herd's size and migration status.

Once again, my heartfelt thanks to the H89ST participants for your time, data, and thoughts for this thesis. Your work is making a huge difference for wildlife in the northern Sierra, and throughout California.

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**Appendix A: Interview Questions for Key Informants: California Highway 89  
Wildlife Crossing Structures Program Evaluation**

**Note: Minor changes to improve interview length and clarity were made to IRB-approved interview questions, based upon a pilot interview conducted on January 17, 2022**

**Introductory Common Questions:**

Do you consent to my recording of this interview? It is required by San Francisco State thesis protocols: protection for you/your statements, and to ensure that I actually held the interview. Also helps me to go back to review answers and compare between respondents – I will be looking for differences but also commonalities, and to identify themes in the answers.

1. To start off, can you please tell me a little about yourself.

What drew you to a career in \_\_\_\_\_ at \_\_\_\_\_.

What brought you to this northern Sierra Mountains area?

2. Thinking back to the early days of the Highway 89 Stewardship Team (H89ST) from roughly 2002 to 2005, do you know how the members of the H89ST were selected?

Were there any other members that you now think should have been on the team?

Who was the “lead” agency and staff person on that team?

3. I have read articles discussing the concept of “adaptive co-management”, which is a strategy that involves collaboration between multiple disciplines, individuals, organizations and levels of government to solve complex issues, and also the strategy of iterative, or experimental problem solving, where the results of the solution are monitored and assessed, and the solution may then be adapted to achieve the best results.

Have you heard about this concept, and do you think that the concept applies to the H89ST?

4. Can you recall if there were any areas of significant agreement or disagreement about the problem of high numbers of wildlife-vehicle collisions on Highway 89?

Or the goals of the team, or how to solve the problem?

Do you recall how often the group met? Was this enough/not enough?

Did the team talk about follow-up monitoring and assessment of the structures?

**Final Common Interview Questions:**

1. In starting to wrap this up, the H89ST concept appears to have been emulated to promote the H17/Laurel Curve Wildlife Crossing Structure project in Santa Cruz County.

Would you say that the adaptive co-management strategy is a helpful concept for wildlife crossings and potentially other wildlife protection strategies?

Do you have any suggestions for improvement of the process?

2. How much progress do you think has been made over the past ten years in completing wildlife-transportation projects, including crossing structures or other wildlife/vehicle collision solutions?

3. Other than what has been raised, are there any other wildlife safety and habitat connectivity programmatic priorities in the next five to ten years for the Sierra County/Northern Sierra Nevada area – for example, other WCS along H89, or Hwy 49? Specific locations, if possible.

4. Have the recent wildfires in this region altered your perspective or priorities for what is needed to protect wildlife in this area?

5. Based on what you know regarding the H89 wildlife crossing structures impact on collision reductions and/or use by wildlife, do you believe the H89 structures have been successful?

Are there any other changes to the process for planning and building or follow-up monitoring for these structures that you would recommend for the future?

**6. Thank you very much for your participation in this interview. Before we close, is there anything else you would like to add to what we've discussed?**

**INDIVIDUAL QUESTIONS FOR KEY INFORMANTS**

**Questions for CA Department of Fish & Wildlife**

**Questions 1.-4.** – refer to “Common Interview Questions”.

5. Regarding the selection of the crossing structure sites, I note that the Sierra County General Plan Wildlife Element (2012) contains mapping of the migratory deer herd. Was that information used in selecting the sites?

Were there other such information sources from agencies, such as the U.S. Forest Service (USFS) or the UC Sagehen Field Station?

6. I understand from prior communication that you ranked and selected the sites during the period from 2002 to 2006. Were the precise Sagehen Pass North and South structure locations (postmile no.'s SIE .8 and SIE 1.4) selected at the same time as the Kyburz Flat location was, or were the locations at Sagehen Pass more general?

7. I'm wondering about factors other than vehicle collision data and field evaluations that may have influenced site selection?

Were the specific Sagehen structure locations were influenced by the Caltrans criteria to mitigate wildlife-vehicle collisions due to vehicle "sight-distance" on this curvy section of road?

Re. Sagehen – I read an article that said that local citizens/drivers provided input that this area was particularly dangerous in terms of avoiding deer. Do you recall that?

I'm also wondering about the attraction of the Kyburz Flat site due to its visibility and location near Tahoe National Forest campsites, and the possibility of public education about wildlife.

Re. Kyburz, I understand that a decision was made to locate all the crossing structures south of a road that diverted a lot of traffic from H89. Was that Henness Pass Road?

8. You have previously noted that other H89 crossing locations were identified during the 2002-2005 period. Can you recall where these locations were, and what solutions were proposed to deal with wildlife-vehicle collisions in those areas?

Do you recall discussion about three small culverts north of Kyburz that were proposed for adaptation for small wildlife (see photo in Jacobson's article)? Do you recall what happened there?

Was the H89 auto bridge over the Little Truckee River also considered as a wildlife undercrossing?

9. Do you recall what the primary influences were on the design and dimensions of the Kyburz (steel arch) versus Sagehen (concrete box) structures?

I understand from reading that there were supposed to be some “experimental differences” in the design and maintenance between the two Sagehen structures – but they look the same to me.

**10.** Do you know if there any legal or funding impediments to designing the WCS – such as overpasses being too expensive? Were there any questions of real property rights and access to build the structures?

What about funding for follow-up monitoring of the completed structures?

**11.** Given that funding for construction of the Kyburz Flat exclusion fencing was approved in 2008, why did it take 5 years after completion of the structure (2013) to install the fencing?

An article I read (K. Wong 2020) indicated that the team hoped to experiment with different types of fencing at Kyburz Flat – did that happen?

**12.** Regarding the “jump-out” escape ramp at Kyburz Flat, I have only seen one ramp. Is there another one?

Do you think the ramps have been successful? I have seen animals other than deer (bears, bobcat) use a ramps near Sagehen, but don’t recall seeing many animals using the one at Kyburz.

**13.** Turning now to broader questions about wildlife conservation efforts, the Department of Fish & Wildlife website articles indicate that the H89ST is still in existence, for example for the proposed Highway 395 Bordertown wildlife crossing project.

Have the member organizations and personnel of the H89ST changed?

Is the H89ST meeting regularly for this project (how often)?

Do you see the H89ST operating outside of Sierra County in the future for wildlife protection projects?

**14.** Regarding the **2010 California Essential Habitat Connectivity Project** plan? Is your department working on an update to this plan - and if so, would there be any changes to the Connectivity Areas, and does this document affect CDFW’s projects and priorities?

Other than the H89 Crossing structures, what other wildlife habitat connectivity projects would be high priority for Area #69?

**15.** Projects outlined in the **CA DFW 2020 California Action Plan** feature Sierra County and the Loyalton-Truckee Deer Herd (see “background” below). Is it fair to say that preservation of the Loyalton-Truckee Deer Herd is one of the top 2 or 3 priorities in California for the CDFW?

Has the deer-collar telemetry data been analyzed and reported on? Is there a shift in their migration routes?

The Action Plan notes that additional structures and fencing are needed on sections of H89 – do you know where those are?

**Remaining Six Questions** – refer to “Final Common Interview Questions” 1. - 6.

### **Questions for CA Department of Transportation (Caltrans)**

**Questions 1.-4.** – refer to “Common Interview Questions”, for Introductory Questions.

**5.** At what point were the actual locations (SIE .8 and SIE 1.4) for the Sagehen structures determined: was it during the Kyburz Flat planning period in 2006, or later?

Please explain Caltrans’ reasoning for how the specific Sagehen sites were chosen? Were vehicle site-distance concerns a big priority? Or site topography, and the ability to construct the undercrossing? I read that there was input from local drivers that these locations were dangerous for WVCs.

**6.** How were the construction type (pipe structure) and dimensions chosen for the Kyburz Flat structure versus the concrete box undercrossings for the Sagehen Pass Structures?

I understand that overpasses were not considered for these locations. Why not, and would these realistically be considered for other locations on H89?

**7.** I have read that the two Sagehen Pass box structures were intended to be somewhat experimental in design- for example the team wanted to experiment with different types of flooring. Can you explain the differences (if any) between the two structures, and whether there has been any evaluation of their differences in usage by wildlife?

Were there experimental fencing materials used in building the structures?

**8.** Would you say that the 2009 Caltrans Wildlife Crossings Guidance Manual or the Caltrans Highway Design Manual has been a helpful guide for installing WCS – what would you suggest for improvement of these Manuals, if anything?

Note: The Manual encourages both collaboration with state, local and NGO partners, and states that monitoring to evaluate for effectiveness is critical – the Manual even gives a reference to different fencing types!

**9.** I have read that in 2019, Caltrans filed a Notice of Exemption (NOE) for the Bordertown Wildlife Crossings Project (SCH #2019100267). Has wildlife carcass data been collected for Highway 395, and does Caltrans or CDFW plan to monitor the structures for carcass data and wildlife use with cameras after construction?

Has the H89ST been involved in planning this project? Has Caltrans held meetings with them?

**10.** The “2010 California Essential Habitat Connectivity Project” identifies Essential Connectivity Area #69, which includes the Sierra Nevada Modoc Plateau, the Sierra Valley and Little Truckee River), including the Sagehen Pass to Kyburz Flat section of H89. Is this something Caltrans would work with CA Department of Fish and Game or other agencies such as USFS to implement? Other than the H89 Crossing structures, what other wildlife habitat connectivity projects would be helpful for Area #69?

**11.** Regarding the FHWA MAP-21 “Moving Ahead for Progress in the 21<sup>st</sup> Century Act”. Does this Act replace SAFETEA LU? Has this act, helped to increase the funding and priority for building wildlife mitigation measures such as WCS?

**12.** Do you think the \$61.5 million in state funding for WCS, and the \$350 in federal funding under the new Infrastructure Bill – both approved this year – is going ramp up more projects here in California?

**13.** California has adopted Regional Conservation Investment Strategies (RCIS) that identify predicted impacts of planned transportation projects to assist in identifying an appropriate level of wildlife mitigation.

Do you think the passage of SB 790 (Sterns) that provides for compensatory mitigation credits for wildlife connectivity projects will provide a big incentive to undertake more of these projects?

Has the Federal Highways Administration (FHWA) has actually approved the use of “advanced mitigation credits” for funding (state/local) transportation projects that create unavoidable environmental impacts to wildlife?

Are there projects in Sierra County where mitigation credits could be generated, such as Bordertown?

Can the mitigation credits be applied statewide or is it only applicable for projects within the same County or region?(Implications: If Statewide, there might be “what’s in it for me” issue for participating local jurisdictions.)

**Remaining Six Questions** – refer to “Common Interview Questions” for Final Questions.

**Interview Questions for U.S. Forest Service (USFS)/USFS Pacific Southwest Research Station**

**Questions 1.-4.** – refer to “Common Interview Questions”.

**5.** When the H89 Kyburz and Sagehen crossing structure locations were selected back in the planning phase of these structures – from 2002 to 2006, were they supported as priority locations by the USFS?

Did the Kyburz Flat Interpretive Area and surrounding recreational facilities have any impact on support by the USFS, or raise any concerns?

**6.** The USFS TNF website posted a notice dated 11/4/2019 about the acceptance of a land donation from the Truckee Donner Land Trust of approximately 982 acres at Perazzo Meadow, west of Kyburz Flat. The notice lists several beneficial effects of the land donation, including to recreational facilities, water quality, and aquatic and terrestrial habitats.

Are Kyburz Flat and Perazzo Meadow considered summer habitat – or year-round habitat - for the Loyalton-Truckee Deer Herd. If so, will the land acquisition assist in protecting the herd, or encroach on it? Is Perazzo Meadows also prime habitat for other species such as aquatic, or birds or small (endangered) animals, such as the fisher?

**7.** In your opinion, does the bridge on H89 at the Little Truckee River also serve as a wildlife undercrossing? Have you seen wildlife, including deer, cross under the bridge?

There was mention in Sandra Jacobson’s article about constructing a “ledge” for small animals to access that bridge undercrossing, was that ever completed, or are there plans to do so? What about the small pipe culverts north of Kyburz Flat – were those culverts improved?

**8.** In general, what role does the USFS have in design, project review, approval and funding for construction or maintenance of roads and highways within the Tahoe National Forest (TNF)? Does the USFS have a particular staff person monitoring all road projects within the region?

Do such road projects generally fall under NEPA regulations? If so, did the USFS hold any such hearings for the H89 wildlife crossing structures?

Do you foresee greater involvement in promoting and reviewing such plans for future crossing structure placement? I saw that the USFS Pacific Southwest Research Station has posted a new publication on Wildlife Crossing Structures as of 2021 on the benefits and use of WCS.

9. Do unpaved forest access roads used for recreation, logging etc. pose a threat to migratory deer and other wildlife, and if so, what kinds of mitigations have you put in place for such roads?

10. The TNF Implementation Plan places an emphasis on federally endangered wildlife species. Given this mission, would you like to see diverse kinds of wildlife crossing structures in the TNF that are geared more toward smaller or different species, such as salamanders and frogs, or smaller mammals such as the fisher?

Are you aware of three small culverts north of Kyburz Flat that were identified as potential wildlife crossings for smaller species during the H89 crossing structure planning process?

11. Is the USFS involved in the proposed Caltrans project, “Bordertown” wildlife crossing project (2020), which would upgrade wildlife crossings/underpasses along H395 and install deer fencing, or the CDFW Smithneck Wildlife Area expansion (2019)?

**Remaining Six Questions** – refer to “Common Interview Questions” for Final Questions.

### **Interview Questions for Sierra County**

**Questions 1.-4.** – refer to “Common Interview Questions”.

5. The Sierra County General Plan, “Plants and Wildlife Element” has some detailed maps that include deer migration corridors and fawning areas. I understand that there are two volumes of background documents related to this that date back to 1974.

Was that study & mapping project used to help decide where the H.89 wildlife crossing structures should be located? Do you know what methods were originally used to determine the deer migration corridors? Are there any plans to update those maps? Has the County had access to the Loyalon-Truckee Deer Herd Telemetry (collar & tracking) study?

6. I understand that Sierra County was a “local match” funding contributor for one of the H89 wildlife crossing structure projects – was it Kyburz Flat, or the Sagehen Crossing Structures? Can you confirm that it was STIP funding (State Transportation Improvement Program? Funding amount?

7. Is the County or the H89ST involved in the proposed Caltrans project, “Bordertown” wildlife crossing project (2020), which would upgrade wildlife crossings/underpasses along H395 and install deer fencing, or the CDFW Smithneck Wildlife Area expansion (2019)?

**8.** Is the Sierra County Fish and Wildlife Commission involved in planning issues involving wildlife-vehicle collision prevention efforts or the H89ST?

**Remaining Six Questions** – refer to “Common Interview Questions” for Final Questions.

**Interview Questions for UC Cooperative Extension Representative**

**Questions 1.-4.** – Refer to “Common Interview Introductory Questions”.

**5.** Did the UC Cooperative Extension representative bring any specific resources or information to the planning of the Kyburz and Sagehen Wildlife Crossing Structures?

Did the UC Cooperative Extension representative have any particular concerns about the H89ST process regarding planning for the crossing structures?

**6.** Did UC Cooperative Extension assist with site evaluation or monitoring the finished structures– such as analysis of camera trap or other data?

**7.** If you recall, did the UC Cooperative Extension representative approve of the selection of the sites for placement of the crossing structures?

Are there other locations that were of concern to the UC Cooperative Extension?

**8.** The H89ST continues to operate in the Sierra County area to promote habitat and connectivity for the Truckee-Loyalton migratory deer herd. Is this a project that the UC Cooperative Extension may be interested in continuing to participate in?

**Remaining Six Questions** – refer to “Common Interview Questions” for Final Questions.