Permeability of Existing Structures for Terrestrial Wildlife: A Passage Assessment System

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16. ABSTRACT A Passage Assessment System (PAS) was developed to help the Washington Department of Transportation (WSDOT) evaluate existing transportation infrastructure for its ability to facilitate terrestrial wildlife movement from one side of a roadway to the other. The outcomes of this research provide mechanisms to allow transportation agencies to identify both opportunities and barriers to wildlife passage along roads. The PAS presented in this report provides an assessment process that differentiates – for different types of wildlife – between structures that are currently functional, those that could be enhanced to become more functional, and those that are not		

based on how the wildlife respond to roads and crossing structures. Structural Functional Classes were also defined to classify road infrastructure, such as bridges, culverts and pipes, to create a common understanding of terminology related to wildlife crossings. The field research was conducted for six months in six locations in central and western Washington with the objective of ascertaining which species of wildlife approached and used different types of structures. The PAS was then developed on the basis of these field data, research on wildlife use of crossings across North America, and the organization provided by the Species Movement Guilds and Structural Functional Classes. The PAS guides practitioners through a series of targeted questions designed to characterize a bridge or culvert relative to its potential to function as a wildlife passage for the full range of wildlife known to occur at a given site. The PAS is intended as an evaluation tool to ensure that biologists ask the right questions in the field and fully document the conditions that may affect passage functionality for the diversity of target species. By answering questions about the structure characteristics, vegetation, land use, roadway, barriers and fencing, the biologist will have a complete passage assessment including preliminary ideas for improving the structure, which can be further refined during the project planning and design processes. The PAS provides an effective mechanism for determining which structures are suitable for enhancements to improve their functionality as wildlife passages or, if no such enhancements are appropriate, identify structure replacement needs for improved highway permeability for wildlife. A Passage Enhancement toolbox is provided to complement the PAS and presents a number of infrastructure adjustments and maintenance actions that may be implemented to help wildlife better move through structures. This toolbox may be used to help guide users in developing site-specific recommendations.

The Passage Assessment System supports timely inclusion of wildlife passage needs from the onset of highway corridor planning, project planning and design. It offers potential cost-savings and minimized project delays by identifying passage modifications that may be significantly less costly than new infrastructure. Where existing culverts and bridges can be shown to pass wildlife, it would help to reduce future construction costs for wildlife crossings in those areas and help to prioritize which areas are lacking in potential crossings and need additional mitigation.

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EXECUTIVE SUMMARY

State Departments of Transportation (DOT's) are exploring ways to mitigate the negative impacts of roads on wildlife, such as the fragmentation of natural landscapes and the mortality of animals that are hit by vehicles. While new bridges and culverts with fencing specifically designed for wildlife passage (wildlife crossings) offer the greatest opportunity for reducing these negative impacts, they may not always be economically feasible or constructed in a timely manner. Complementing new wildlife crossings, there are also numerous opportunities to enhance existing transportation infrastructure. Hundreds to thousands of culverts and bridges are currently part of the Washington's transportation system and may function to pass wildlife. With small modifications, many of these existing bridges and culverts could be upgraded to provide greater permeability for wildlife and ecosystem processes at lower cost and on shorter time frames than needed for new wildlife crossings.

The purpose of this project was to create an assessment methodology to evaluate existing transportation infrastructure for its ability to facilitate wildlife movement from one side of a roadway to the other. To accomplish this, the research team developed initial criteria for assessing the permeability of existing bridges and culverts for terrestrial wildlife based on the current body of knowledge on how wildlife native to Washington use wildlife crossing structures. The assessment methodology – named the Passage Assessment System (PAS) – was then field tested along Washington roads in linkage areas identified in the Washington statewide habitat connectivity assessment (WHCWG 2010). To complement and validate the field test, the team also conducted wildlife monitoring at seven locations using remote motion-triggered cameras. Data compiled through the monitoring effort served to refine an understanding of how wildlife used select culverts and bridges, which could then be generalized to other locations. The process was then brought to WSDOT biologists in April of 2011 and, through a field test with these future users of the system, the process was further refined. The PAS is a living document, able to be updated to incorporate new understandings of wildlife passage and behavior as they become available, and tailored to address regionally specific wildlife adaptations.

In developing the PAS, it became first necessary to create an explicit process for assessing the characteristics of the various types of bridges and culverts, as well as defining how landscape and structure attributes affect a species' willingness to pass through a structure. To create such an objective standardized process, the researchers began by refining classification systems for wildlife relative to their behavior and perceptions of potential crossing structure, and a second system to provide a common vocabulary for describing the variety of roadway structures that may function as wildlife passages (e.g., culverts, bridges and overpasses). These classification systems were based on a thorough review of the literature base; contributed knowledge from the researchers' concurrent field studies of wildlife and roads in Colorado, Utah, and Montana; and compiled research from colleagues across North America to formulate a more complete understanding of wildlife preferences

and behavior at crossing structures. The wildlife monitoring conducted in Washington as a part of this project further informed an understanding of regional preferences and behavior.

The resulting classification of 'Species Movement Guilds' (Chapter 2.2.) categorizes wildlife based on their modes of locomotion and preferred crossing structure characteristics as understood from past and current scientific studies. This is a unique classification designed to facilitate an understanding of 'what works' for different types of wildlife. The classification system allows transportation biologists to evaluate the physical and environmental conditions and potential constraints to movement from the perspective of groups of species, and develop mitigation strategies that carefully consider the behavior and preferences of each target species. The Guilds facilitate an understanding of why certain species have specific requirements and allow generalizations to be made across species in a given Guild thereby streamlining project planning and design processes.

Eight Species Movement Guilds are defined (Table 1): Low Mobility Small Fauna, Moderate Mobility Small Fauna, Adaptive High Mobility Fauna, High Openness High Mobility Carnivores, Adaptive Ungulates, Very High Openness Fauna, Arboreal Fauna, and Aerial Fauna. These Guilds provide a classification for mitigating impacts to wildlife whose habitat or movement paths are bisected by a transportation corridor. Interested biologists may not know if a particular species has been studied relative to the effectiveness of various mitigation strategies. By placing that species within its respective Species Movement Guild, generalizations can be made as to which mitigation solutions could be implemented for that species. The Species Movement Guild classification represents the best gathering of the current state of the science of wildlife and transportation in the United States and Canada.

Table 1. Species Movement Guilds

Movement Guild	**Typical Species of That Guild**
Low Mobility Small Fauna	Invertebrates, frogs, toads, some salamanders
Moderate Mobility Small Fauna	Squirrels, raccoons, hares, weasels
Adaptive High Mobility Fauna	Black bear, bobcat, coyote, lynx
High Openness, High Mobility Carnivores	Grizzly bear, mountain lion, wolf
Adaptive Ungulates	Deer, moose, mountain goat
Very High Openness Fauna	Elk, bighorn sheep, pronghorn antelope
Arboreal Fauna	Flying squirrels, some bats
Aerial Fauna	Songbirds, raptors, bats

The second classification scheme, 'Structure Functional Classes' (Chapter 2.3) provides a breakdown of the types of road crossing structures that can provide passageways for wildlife under or over a roadway (i.e., small underpasses, medium underpasses, large underpasses, extensive bridges, wildlife overpasses, specialized culverts and canopy bridges), and the types of wildlife that may use these structures.

The term 'wildlife underpasses' connotes many different structures from the smallest culverts that may pass a salamander, to the space under a highway viaduct. A classification of transportation infrastructure into defined Structure Functional Classes provides a definitive set of conditions for four different underpasses, the overpass, and two distinct designs for passages (Table 2). The critical dimensions for breaks among the four classes are based on heights and widths of structures, which are dictated by engineering design constraints as well as the characteristics that define individual species' willingness to move through a structure. This classification of structure types can help transportation planners, biologists and engineers to relate wildlife passage needs to a specific structure type or types using a common vocabulary.

Table 2. Structure Functional Classes

Class Type	**Class Name**	**Typical Species the Structure Type is Known to Pass**
Class 1	Small Underpass	Amphibians, small mammals
Class 2	Medium Underpass	Coyote, bobcat
Class 3	Large Underpass	Deer, elk, black bear
Class 4	Extensive Bridge	Most wildlife – wary species
Class 5	Wildlife Overpass	Most wildlife, including birds
Class 6	Specialized Culverts	Reptiles & amphibians
Class 7	Canopy Bridges	Flying squirrels, arboreal rodents

Combined, the Species Movement Guilds and the Structure Functional Classes lay the foundation for evaluating the permeability of existing structures for wildlife. The team then developed initial structure evaluation criteria based on research in other states supplemented with published research and correspondence with colleagues to determine the factors that appear to influence wildlife passage and how they should be parameterized. These factors include structure dimensions, passageway substrate, vegetation cover, landscape attributes and human use, among other considerations.

A field research component of this project was conducted in conjunction with the development of the Passage Assessment System (PAS). This field component was carried out to better inform the knowledgebase specific to the use of transportation infrastructure by wildlife in Washington. Motion-triggered trail cameras were placed at seven sites across Washington. These sites were selected to best represent different geographic areas, roads with variable number of lanes and different traffic volumes, and different types of structures. Sites were monitored along US 101 in southwestern Washington, and I-90 in west-central Washington. At each site a camera was positioned at each end of the structure to best monitor all animal approaches and passes through the structures.

Monitoring information can help WSDOT determine which species will use certain structures more readily than others. Detailed summaries of the results are provided in the Appendices of this report. In general, every structure monitored passes either mule deer (East of Snoqualmie Pass) or black-tailed deer (western part of the state). These structures included bridges which were expected to pass these deer, and concrete box culverts less than five feet high, a surprising result, perhaps due to a local adaptation necessitated by high traffic volumes on I-90. Photographic data from the Mosquito Creek culvert under US 101 (milepost 76.5), and the double box culvert under I-90 at Tucker Creek (milepost 73) showed a surprising amount of black-tailed deer using the Mosquito Creek/US 101 culvert, and mule deer using the Tucker Cree/I-90 box culvert. The Mosquito Creek culvert is only seven feet (2.1 m) high, less than 16 feet (14.9 m) wide in span, and 138 feet (42 m) long. The I-90 double box culverts at Tucker Creek are less than five feet (1.5 m) high, nine feet (2.7 m) in span, and 58 feet (17.7 m) long for each of the two culverts under opposing lanes of traffic. These culvert heights are typically considered too small for more than occasional mule deer passage. The data from these cameras continue to inform our ideas of how deer will adapt to structures and suggest a need for additional research into the factors that affect passage use, such as traffic volumes, local adaptation, and habitat drivers, among others.

Research throughout the western United States has documented elk's reluctance to pass through confined spaces such as culverts or small, restricted bridges This study documented elk use of two large bridged structures under I-90, one at the South Fork Snoqualmie River near milepost 33, the other at the Cle Elum River near milepost 79. This research project demonstrated elk movements under bridges that were wide, but less than 10 feet (3.1 m) high where the elk pass under the bridge. This new insight that elk may be willing to use low bridges so long as they are sufficiently wide helped inform the requirements quoted for elk in the Species Movement Guilds description (Section 2.2.1-6) and may help WSDOT and other agencies to better design cost-effective bridges suitable for elk.

Black bear were photographed using a set of large culverts near the town of North Bend, to navigate under I-90. The culverts are 12 feet (3.7 m) high and 29 feet (8.8 m) in span and are tied in to wildlife fencing in both directions. These culverts appears to be among the most successful black bear crossings in the western U.S., as demonstrated by 31 black bear observations during five months of study. In comparison, study sites in two states combined (Montana and Utah) have tallied less than 12 successful black bear crossings over the course of two years. While the passage is very successful for black bear, only three bobcats approached and crossed through the structure, and seven of 19 approaches by coyotes were repelled. This may explain the low numbers of deer using it. It may also support the idea that in an area of high species diversity, multiple crossings may be necessary for prey, predator and even competitor species.

This compilation of nationwide and local monitoring information was incorporated for the development of a systematic process for evaluating existing transportation infrastructure. The Passage Assessment System (PAS) guides practitioners through a series of targeted questions designed to characterize a bridge or culvert relative to its potential to functions as a wildlife passage. The PAS is one of several complementary tools to assist WSDOT in identifying important connectivity areas and design mitigation solutions to improve or restore permeability for native wildlife. While the Washington Wildlife Habitat Connectivity Analysis (WHCWG 2010) offers a broad-scale perspective of connectivity across the state, the PAS allows WSDOT biologists to assess permeability at the site scale, for example along targeted stretches of roadway identified as bisecting these landscape connections.

To begin the assessment process, it is necessary to first select the roadway segments of interests before conducting the PAS in the field. These may be areas that are identified connectivity zones; areas with high levels of animal-vehicle collisions, as determined from carcass removal data; areas that are slated for upcoming projects in short-term (3-5 year) planning or longer term (5-15 year) corridor planning; or, preferably, a combination of the above. The next step before taking the PAS into the field is to identify the species of interest whose habitat is bisected or adjacent to the roadway, and for which movement from one side of the road to the other may be of concern. In general, target species include those that are of danger in animal-vehicle collisions, such as deer, elk and moose; species of concern such as forest carnivores and threatened and endangered species; and other species that are sensitive to the barrier effect of roads. The Wildlife Habitat Connectivity Analysis identified 16 focal species for the connectivity analysis. These species, if they occur in the geographic area of interest, should be included as target species. Appendix A identifies target species and associated Species Movement Guilds for each ecoregion in the state.

The assessment questions that compose the PAS were derived from a similar assessment system used in Colorado (Kintsch et al. 2011) and were further refined through a field test in Florida conducted by one of the researchers (Cramer). Following an additional series of refinements in collaboration with WSDOT, the researchers conducted a one-week field test, visiting 17 sites in southern and central Washington, including sites representing multiple bioregions and a range of structure types (pipe culverts, box culverts, arch culverts, small bridge underpasses and large bridge underpasses) as well as road types (from two to six lanes, including both divided and undivided highways). See Appendix D for complete site summaries. Final refinements to the PAS were made based on monitoring results and feedback an April 2011 workshop where the PAS was presented to WSDOT biologists from across the state.

The PAS is composed of three sections: General Questions, Undivided Highway, and Divided Highway, as well as a User's Guide provided for additional reference. For each structure that is being evaluated the user will complete 1) the General Assessment Questions, and 2) either the Divided or Undivided Highway Assessment Questions, depending on whether the structure of interest is located on a divided or undivided highway. Each of the questions in all three sections is fully clarified in the User's Guide. The complete PAS is available in hardcopy format in Appendix B of this report, or a digital copy is available from the Fish and Wildlife page of WSDOT's intranet. It is recommended that two biologists conduct the PAS together to capture a more comprehensive picture of a structure's passage characteristics.

The General Assessment Questions record general information about the site, including a milepost, GPS point, a unique location code, the Structure Functional Class Type, the Species Movement Guilds present at that site, and whether the highway is divided or undivided. The answer to this last question – divided or undivided highway – will determine which form the user completes next, either the Divided or Undivided Highway Assessment Questions. While the questions posed are the same for a divided or undivided highway, they must be posed independently for each structure at a divided highway site.

At the start of the form the user is asked to respond to a set of preliminary questions. These are a collection of targeted questions designed to determine if there is a 'fatal flaw' with the structure relative to the Species Movement Guild(s) of interest. Each question should be considered relative to the Species Movement Guilds indicated. If a fatal flaw is identified, then the user need not complete the remaining PAS questions as the fatal flaw renders the structure unsuitable for enhancement; a redesigned and reconstructed structure is required to pass wildlife at that location. Fatal flaws may be specific to some or all Guilds and include situations where a culvert is too long for the target species to pass through or where there is a lack of visibility from one end of a structure to the other.

If no fatal flaws are identified, the user then continues with the remaining questions, which are divided into distinct sections to guide the evaluation process. The assessment questions address the structures size and shape, lanes of traffic, other nearby structures, inlet and outlet features, water flow, visibility, vegetation, nearby land use and fencing, evidence of wildlife use and any human use. Throughout the PAS, users are encouraged to take a number of photos from multiple directions to fully capture a visual record of the structure and its attributes.

Finally, the user is instructed to document their general impressions regarding the functionality of the structure for each of the Species Movement Guilds of interest. For each Guild, the user is instructed to rank the structure such that an A rank means that animals could pass through the structure as is or with small modifications; a C rank means that the structure could be functional with modest modification; and an F rank means that the structure cannot be enhanced to function as a wildlife passage. This section is a subjective assessment and responses should be based on the user's overall impression having completed the full PAS. Users are then asked which features could be changed to make the structure more functional for any Species Movement Guild of interest given an A or C rank.

This question offers an opportunity for the user to suggest potential improvements. These may be amended and refined later, but this evaluation is helpful for capturing preliminary ideas and impressions while still in the field.

Upon completing the PAS the user will be equipped to answer the question: 'can this structure be improved to accommodate passage for the target species present in this area?' It is possible, in some cases, that a given structure may be enhanced to accommodate one or several of the target species, but cannot be suitably improved to accommodate all target species.

Having determined that a structure *can* be enhanced for wildlife passage, biologists are then confronted with the question of *how* to enhance the structure to facilitate passage. Given the unique characteristics of every structure and the specific permeability objectives at each site, there is no simple answer to this question, however a number of commonly encountered situations are addressed in the Passage Enhancement Toolbox (Appendix C). The toolbox addresses a number of situations and provides examples of each. The user is encouraged to consider the range of possible enhancements and how they could be implemented at each site being assessed.

The Passage Assessment System supports timely inclusion of wildlife passage needs from the onset of highway corridor planning, project planning and design. It offers potential cost-savings over new structures and minimizes project delays by identifying passage modifications that may be significantly less costly than anticipated. If existing culverts and bridges can be shown to pass wildlife, it would help to reduce future construction costs for wildlife crossings in those areas and help to prioritize which areas are lacking in potential crossings and need immediate mitigation. The PAS can also be used to identify areas where maintenance and daily operations activities could significantly improve existing infrastructure for wildlife movement outside of projects. PAS should be considered a living document as new research reveals how passage characteristics affect permeability for different types of species.

There are a number of ways in which the PAS may be enhanced over time to facilitate the assessment process and guide the design of appropriate mitigation enhancements. Notably, while the PAS is currently available as hard copy data forms for use in the fields, it is also ready to be programmed into handheld GPS-data collection units. Two such units are currently being beta-tested by the USDA Forest Service (contact: S. Jacobson). These units provide a streamlined mechanism for collecting and compiling field data. Both the hard copy forms and the programmable units may be easily updated and refined as needed.

In addition, ongoing and new monitoring studies that help deepen our understanding of wildlife responses to crossing structures may also further inform and refine the PAS over time. With the deployment of field research cameras across Washington, WSDOT will be better equipped to record species' responses to transportation infrastructure and traffic. These data will greatly assist WSDOT in developing wildlife crossing structures and enhancements to existing structures that will improve the permeability of the state's road network for all wildlife.

As the knowledgebase of what works and doesn't work for different species evolves, DOTs will be increasingly equipped to design effective new wildlife crossing structures and improve the functionality of existing structures. Targeted monitoring where permeability enhancements have been implemented will create a positive feedback loop for maximizing the effectiveness of future improvements. Tools such as the PAS can help DOTs direct transportation dollars for maximum effectiveness and cost efficiency.

CHAPTER 1. INTRODUCTION

The science and practice of transportation ecology is concerned with the effects of transportation on the natural world and the measures necessary to help avoid, minimize and mitigate those effects. In a world largely dependent upon motorized transport of people, goods and services, the negative consequences to individual plants and animals and entire ecosystems is inevitable. Both the road footprint and vehicular traffic pose threats to intact ecosystems and wildlife by creating barriers to movement of individuals and natural processes, fragmenting natural communities, and causing numerous vehicle collision-related deaths. At the heart of the practice of transportation ecology is the belief that new transportation projects should first avoid natural areas and crucial wildlife core areas and corridors; second, plans should minimize those effects; and lastly, mitigate for the effects of a project on wildlife, natural habitat and ecosystem processes. In the case of existing transportation infrastructure that is still in use, mitigation is the only option available for improving roadway situations to accommodate multiple wildlife species and their movements across the landscape, thereby promoting wildlife permeability.

The negative effects of roads including the fragmentation of natural landscapes and the mortality of animals that are hit by vehicles can be partially mitigated through improvements to existing infrastructure to enhance permeability for wildlife. While new crossing structures designed specifically for wildlife passage offer the greatest opportunity for reducing the negative impacts of roads on wildlife, such large infrastructure projects are often not economically feasible or constructed in a timely manner. Hundreds to thousands of culverts and bridges are currently part of the state's transportation infrastructure and may function to pass wildlife. With small modifications, many of these existing bridges and culverts could be upgraded to provide greater permeability for wildlife and ecosystem processes.

Efforts are underway nationwide to better plan new transportation projects and upgrades to existing transportation infrastructure in ways that help to minimize the negative effects of roads on the natural environment, natural process and wildlife movement. Such integrative planning efforts begin at the long-range planning stage, where initial environmental needs and mitigation costs are assessed. To properly inform these long-range planning efforts there is a need to assess existing infrastructure for its current and potential ability to function as passageways for different types of wildlife. Inclusion of wildlife permeability needs at the outset of project planning effectively promotes landscape connectivity to help minimize transportation impacts in a cost-effective fashion.

While there are many studies documenting individual species' preferences for crossing structures across the continent and the globe, until this research project, there has not been a complete analysis of functional crossing structure characteristics for diverse wildlife species. In addition, while transportation agencies across North America and Europe have instituted various types of enhancements to existing infrastructure to promote permeability for wildlife at a number of locations, a clear process for understanding and defining the structural and landscape characteristics that enhance or impede movement through a structure for diverse types of wildlife has been lacking.

Consequently, the Washington State Department of Transportation (WSDOT) has been without a means for understanding how transportation infrastructure currently functions to support or impede connectivity for terrestrial wildlife. In supporting this research, WSDOT identified a concrete need for protocols for evaluating existing structures – bridges and culverts – with regards to their potential to pass different types of wildlife. The outcomes of this research provide these mechanisms, allowing transportation agencies to identify both opportunities and barriers to wildlife passage. The Passage Assessment System (PAS) presented in this report provides an assessment process that differentiates – for different types of wildlife – between structures that are currently functional, those that could be enhanced to become more functional, and those that are not functional for wildlife passage. In this manner, the system enables transportation agencies to prioritize these enhancement opportunities for the greatest cost efficiency, and identify locations where improved permeability will require new infrastructure investments.

The Passage Assessment System supports timely inclusion of wildlife passage needs from the onset of highway corridor planning, project planning and design. It offers potential cost-savings over new structures and minimizes project delays by identifying passage modifications that may be significantly less costly than anticipated. If existing culverts and bridges can be shown to pass wildlife, it would help to reduce future construction costs for wildlife crossings in those areas and help to prioritize which areas are lacking in potential crossings and need immediate mitigation. The process also assists in ecological considerations because it targets priority areas where functional passages do not currently exist. The PAS, in conjunction with Washington's recently completed statewide Wildlife Habitat Connectivity Analysis (WHCWG 2010) and the statewide carcass removal database, form the basis for targeting mitigation dollars and incorporating wildlife needs early in the transportation planning process to inform infrastructure designs prior to project development and thereby help minimize delays. The PAS can also be used to identify areas where maintenance and daily operations activities could significantly improve existing infrastructure for wildlife movement outside of projects.

1.1. History of Landscape Permeability in Washington State

Since 1991 WSDOT has managed a cooperative program to inventory, prioritize, and correct fish passage barriers along state roads. More recently, WSDOT has recognized the need for creating an analogous process for identifying and assessing connectivity needs for terrestrial wildlife across state roads, of which this Passage Assessment System is a step.

In July 2007, Washington State Secretary of Transportation Douglas MacDonald signed Executive Order 1031 'Protections and Connections for High Quality Natural Habitats', which directs the agency to protect ecosystem health and preservation of biodiversity through the road and highways programs. This order directs WSDOT to protect aquatic and terrestrial connectivity for fish and wildlife. As part of WSDOT's actions to fulfill this order, WSDOT and its partners in the Washington Wildlife Habitat Connectivity Working Group released the statewide Washington Wildlife Habitat Connectivity Analysis (WHCWG 2010). This document provides maps based on scientific analyses of how 16 target species of wildlife may need to move across the state through connected networks and where the most intact connected landscapes occur throughout the state. This connectivity assessment, in combination with other information, will influence road corridor plans and highway improvement projects, and will help to prioritize highway segments for receiving funds for wildlife-friendly improvements.

With these multiple approaches to identify and maintain terrestrial and aquatic connectivity across Washington roads, it is a logical next step to create a method to assess how well existing infrastructures passes terrestrial wildlife. The results of this assessment method could then in turn be used to improve existing structures in small and large ways to assist wildlife and natural process movement, such as the flow of water. It is an important step in the process of "protecting connections for high quality habitats" as directed by Executive Order 1031.

1.2. The Science of Wildlife Use of Transportation Infrastructure

Designing wildlife crossings – new structures as well as enhancements to existing infrastructures – is based on research documenting how different species and taxonomic groups of wildlife have used wildlife crossings in past and current studies. In addition, more general information about the behavioral characteristics and habitat needs of that species can be used to further inform crossing designs, particularly where little or no research has been conducted on an individual species' use of crossings. Improving roads for wildlife permeability has been studied since

1975 when Colorado's first mule deer culvert under Interstate 70 was monitored for mule deer use (Reed et al. 1975). Since that time many states have benefited from the several dozen studies monitoring wildlife use of culverts and bridges across the continent. While the first wildlife crossings were constructed for a specific target species, such as deer or Florida panther, biologists soon learned that designing wildlife passages for the full suite of species found in an area can benefit all of the wildlife present in that area and can help maintain ecosystem processes, such as hydrologic flow (Foster and Humphrey 1995). It is now common, though perhaps not standard practice, to design new wildlife passages for suites of animals. Designing crossings and improving existing infrastructure therefore requires understanding how multiple species may perceive and, subsequently, use a passage. For example, a passage designed primarily for large ungulates can be modified to also accommodate smaller animals and aquatic species. As transportation agencies move towards incorporating more wildlife-friendly practices in their designs, construction and operations, such multi-species considerations are prudent.

1.2.1. Types of Wildlife Passages

A wildlife crossing is a structure that allows wildlife to pass over or under the road. A wildlife crossing structure is designed and built specifically or in part to assist in wildlife movement (Bissonette and Cramer 2008) and include both overpasses and underpasses. Overpasses are built to allow wildlife to move over the flow of traffic to get to the other side of the roadway (Fig.1). Underpasses are much more common and entail two different types of structures, culverts and bridges, both of which allow wildlife to move under the roadway. Bridged wildlife passages can be single span bridges where the structure rests on abutments with no intermediate support columns (Fig. 2). Multi-span bridges are on abutments as well but also have one or more intermediate support columns between abutments (Fig. 3). Culvert underpasses are conduits for wildlife under the road that have an embankment around the entire perimeter. Typically either

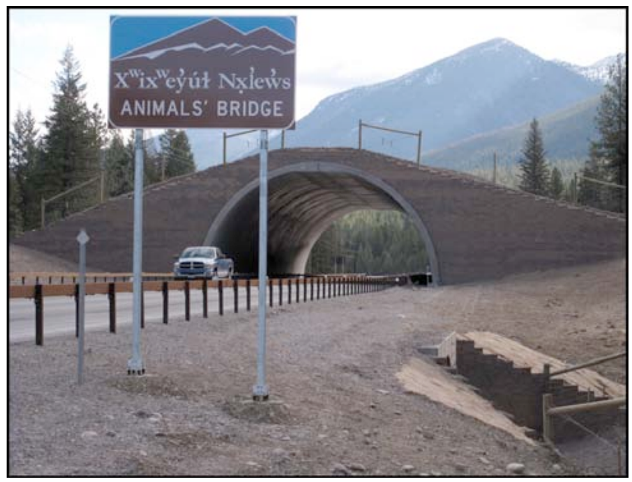


Figure 1. Wildlife overpass over Highway 93, MT © P. Cramer

Figure 2. Single span bridge wildlife crossing in Utah, under US 6 © P. Cramer

concrete box culverts (Fig. 4) or corrugated steel plate arch culverts are used (Fig. 5). More recently, a new arch design for wildlife passages that is intermediate between bridges and culverts has been constructed. An arch crossing consists of pre-fabricated six foot-wide arch spans that rest on abutments and are fastened together to form an arched passageway beneath the road. There is some soil at the sides of the arches, but the abutments are large enough that there are two to one slopes coming off of them to the passage area, making the entrance appear more like a bridged structure than a culvert (Fig. 6)

Figure 3. Multi-span bridge functioning as a crossing under I-70, Colorado © Center for Native Ecosystems, ECO-resolutions, LLC & CDOT

Figure 4. Concrete culvert under US 101 in Washington with black-tailed deer doe and fawns © P. Cramer, J. Kintsch, & WSDOT

Figure 5. Black bear entering a multi-plate steel arch culvert “game crossing” under I-90 in Washington (built in 1976) © P. Cramer, J. Kintsch, & WSDOT

Figure 6. Arch span wildlife crossing in Utah under I-70 © P. Cramer

1.2.2. Overview of Factors Affecting Wildlife Use of Crossings

There are many interrelated factors that affect an individual animal or a population's decisions to use crossings. The two main factors that affect these decisions can be grouped into characteristics of the external environment and internal motivations based on the biology of the species. Understanding why animals behave the way they do and their basic biological needs is an essential component to help planners, biologists and engineers design suitable wildlife crossings and enhance existing infrastructure that considers both the internal and external factors motivating animals to use or avoid a given structure.

Biological factors important to wildlife movement include the following (note that not all of these factors are of equal importance for all species):

- Mode of locomotion, i.e., crawling animals move differently than running animals and may spend more time in a crossing structure;
- Predator avoidance strategies, i.e., the need for prey species to feel safe using a crossing structure;
- Defense strategies, i.e., skunks stop to spray a threat, while porcupines back up to it, and rabbits and deer may run in a zigzag fashion;
- Herd mentality versus solitary movement;
- The need to access basic resources such as food and water;
- The need to find mates;
- The need to migrate to meet basic biological needs such as breeding, calving, egg laying, or access to winter and summer habitats;
- The need to escape human pressures such as development or recreational activities;
- The need to disperse to establish new territories;
- The need for specific types of habitat such as a semi-aquatic condition.

Environmental factors that affect how wildlife perceives structures for potential passage include (note that not all of these factors are of equal importance for all species):

- The presence of natural area or specific habitat on both sides of the road;
- The presence of human development or disturbance nearby or within the structure;
- Vegetative cover leading to the structure;
- Vegetative or woody debris cover within a structure;
- Visibility through the structure and at the approaches to the structure;
- Light contrast inside and outside of the structure;
- Elevation gradients that may affect water flow or large gradients that may affect an animal's approach to a structure;

- Traffic noise that is present outside the structure and that may be amplified inside or changed in pitch inside or beneath the structure;
- Traffic volumes, i.e., heavy traffic volumes may deter animals from coming near the road, and crossing through a structure, while low traffic volumes may encourage animals to cross at-grade rather than use structures unless they are otherwise prevented from doing so with fences or other funneling devices;
- Similarity of the conditions in, under or on a structure relative to the natural environment in which it is located;
- The feel of openness (rather than confinement) for an animal crossing through a structure.

Openness ratio has been a much-discussed and frequently misused metric for assessing the functionality of crossing structures for wildlife, and for this reason it is briefly addressed here. Openness ratio – defined as (height x width)/length, in meters – was originally derived as a threshold measure for comparing the relative openness of various box culverts for use by mule deer, given their preference for a clear line of site through a structure (Reed et al. 1979). This measure has since been extrapolated beyond its intended use and applied to all kinds of structure shapes, leading to confusion in how to measure structures other than boxes, and has been applied to a variety of species, with different minimum thresholds indicated for different species. Other complications in relying on openness ratio as a measure of structure functionality include how the ratio – which is unit-specific – is calculated; how skylights and grates affect the length metric; and a failure to differentiate between the value of height (rise) vs. width (span) in affecting the likelihood of animal using a structure (Jacobson and Jacobson 2007). While researchers agree that the concept of structure openness is an essential factor influencing passage functionality for some types of species, such as deer and elk, Clevenger et al.(2002) noted that openness may become a less important variable influencing culvert use as animals become familiar with particular structures, versus animals that are encountering a structure for the first time, in which case openness may play a greater role. For these reasons, it is not advised to use openness ratio to calculate thresholds for evaluating the functionality of a given structure, and it is not included in the Passage Assessment System.

Jacobson and Jacobson (2007) provide alternative measures to openness ratio for white-tailed deer that consider predator avoidance strategies. These include aspect ratio, a measure of structure length and height at the level of a deer's head; cross-sectional area, a measure of structure shape relative to a deer's perception of openness; brightness, a measure of perceived distance to safety; and presence of a ledge, which can influence an animal's willingness to pass through a structure. While these measures have not been tested or refined for other species, concepts such as these were used in the development of the Passage Assessment System presented in this report.

Past and current research projects are typically designed to measure one or several of these factors and how they influence passage for a given species. Rarely have all of these factors been studied relative to the full suite of species present at a study location.

CHAPTER 2. RESEARCH APPROACH

The purpose of this project was to create an assessment methodology to evaluate existing transportation infrastructure for its ability to facilitate wildlife movement from one side of a roadway to the other. To accomplish this, the research team developed initial criteria for assessing the permeability of existing bridges and culverts based on the current body of knowledge on how wildlife native to Washington uses wildlife crossings. The assessment methodology – named the Passage Assessment System (PAS) – was then field tested along Washington roads in linkage areas identified in the Washington statewide habitat connectivity assessment. To complement and validate the field test, the team also conducted wildlife monitoring at seven locations using remote motion-triggered cameras. Data compiled through the monitoring effort served to refine an understanding of how wildlife used select culverts and bridges, which could then be generalized to other locations. The process was then brought to WSDOT biologists in April of 2011 and, through a field test with these future users of the system, the process was further refined. It is a living document, able to be updated to incorporate new understandings of wildlife passage and behavior as they become available, and tailored to address regionally specific wildlife adaptations.

To create the PAS, it was first necessary to develop an explicit process for assessing the characteristics of the various types of bridges and culverts as well as how landscape and structure attributes affect a species willingness to pass through. Taking a synthesis approach, the team reviewed the current literature base and complimented this with knowledge gleaned from our concurrent studies in Colorado, Utah, and Montana and from research colleagues across North America to formulate a more complete understanding of wildlife preferences and behavior at crossing structures. The wildlife monitoring conducted in Washington as a part of this project further helped to develop a more definitive understanding of regional preferences and behavior.

Using this base of information, the team developed two interrelated classification schemes. The classification of 'Species Movement Guilds' (Chapter 2.2.) categorizes wildlife based on their modes of locomotion and preferred crossing structure characteristics as understood from past and current scientific studies. This is a unique classification designed to facilitate an understanding of 'what works' for different types of wildlife. The classification system allows transportation biologists to evaluate the physical and environmental conditions and potential constraints to movement from the perspective of groups of species, and develop mitigation strategies that carefully consider the behavior and preferences of each target species.

The classification 'Structure Functional Classes' (Chapter 2.3) provides a breakdown of the types of road crossing structures that can provide passageways for wildlife under or over a roadway (i.e., small underpasses, medium underpasses, large underpasses, extensive bridges, wildlife overpasses, specialized culverts and canopy bridges), and the types of wildlife that may use these structures. Combined, the Species Movement Guilds and the Structure Functional Classes lay the foundation for evaluating the permeability of existing structures for wildlife. The team then developed initial structure evaluation criteria based on research in other states supplemented with published research and correspondence with colleagues to determine the factors that appear to influence wildlife passage and how they should be parameterized. These factors include structure dimensions, passageway substrate, vegetation cover, landscape attributes and human use, among other considerations.

The Passage Assessment System is a tool for transportation biologists to evaluate existing bridges, culverts and overpasses relative to their functionality as potential wildlife crossings. The PAS does not and cannot provide a definitive answer as to how to modify existing infrastructure to better accommodate terrestrial wildlife passage; instead, the PAS guides the user through the thought process of identifying the characteristics that impede or promote wildlife passage for different types of species, ensuring that all the relevant factors are fully considered, from a species perspective. In combination with other resources, such as the Passage Enhancement Toolbox provided in Appendix C, users are provided with a framework for identifying if a structure can be modified to accommodate the target wildlife and, if so, which modifications are warranted.

2.1. Previous Roadway Infrastructure Evaluation Studies

Across the country, DOTs are increasingly integrating permeability for terrestrial and aquatic wildlife into transportation projects to mitigate transportation impacts or, in many cases, restore connectivity that has been lost. Efforts to evaluate permeability needs range from informal field visits to detailed manuals for enhancing aquatic connectivity through culverts (e.g., Washington Department of Fish and Wildlife 2000). While a number of states, particularly in the west, have conducted wildlife habitat connectivity assessments of varying levels of analysis and detail, to date, no states have a complete inventory and assessment of transportation infrastructure as it relates to identified wildlife connectivity zones for terrestrial wildlife. In-the-field assessments of potential modifications to existing infrastructure can be conducted well in advance of transportation planning schedules, allowing planners to incorporate wildlife permeability considerations into project designs and budgets. In addition, such assessments may reveal small modifications that can be made outside of project planning through ongoing operations and maintenance, with great benefits to wildlife movement, for example, by removing fencing blocking culvert entrances, clearing debris blocking passage through culverts, or by adding soil over riprap under bridges to create a dry, stable pathway for wildlife to cross over.

In Colorado, a three-year study of the Interstate 70 corridor developed a basic framework for evaluating existing bridges and culverts. This study was supplemented by camera monitoring at select locations in an effort to identify key segments of roadway for wildlife connectivity and to develop recommendations for improving permeability in these areas (Kintsch et al. 2011). The evaluation processes conducted on I-70 directly informed the development of the Passage Assessment System created for this research project.

The Massachusetts Department of Transportation published a report that presents considerations for evaluating existing structures at freshwater streams and offers best practices for accommodating wildlife passage at these road-stream crossings (Massachusetts Department of Transportation 2010). This evaluation system provides a simple field assessment for rating road-stream crossings for terrestrial and aquatic passage on a scale from 0 (severe barrier) to 10 (meets optimal standards). The rating system considers only three factors influencing terrestrial passage – the presence of barriers, openness ratio and minimum clearance – and does not distinguish among the diversity of wildlife species. In contrast, the PAS presented here includes a number of variables that influence the likelihood of successful passage and provides guidelines for assessing how crossing characteristics may affect different species differently.

Field-based assessments of existing transportation infrastructure in other states have occurred on an ad-hoc basis or, in the case of Utah, limited to a broad-scale and subjective evaluation of barriers to connectivity across specific highway corridors (Utah Department of Transportation 2007).

2.2. Species Movement Guilds

The Species Movement Guilds (Table 1) are a classification of terrestrial wildlife species based on their responses to roads and crossing structures – behavior that is largely influenced by predator detection and avoidance strategies, as well as an animal's size and capacity for locomotion. Traditional species classifications are based on taxonomic groupings based on biologic similarities among species. In contrast, the Species Movement Guilds classification was developed specifically for the purpose of designing species-specific wildlife crossings and evaluating the influential characteristics that render a structure functional or non-functional. Previous studies in road ecology have proffered similar classifications more closely tied to taxonomic classifications (e.g., Grillo et al. 2010), or based on body size (Clevenger and Kociolek 2006) and how species respond to habitat fragmentation (Cavallaro et al. 2005). Clevenger and Huijser (2009) developed a size-based classification that considers fragmentation impacts as well as species area requirements.

The Species Movement Guilds presented in this report are intended to be a refinement of these previous classifications, including an in-depth discussion and justification for the groupings. The guilds categorize wildlife based on body size – which puts a physical limit on the structures that a given species can use – how they move, how they respond to roadway traffic or potential threats such as predators, and the crossing structure characteristics, such as vegetation cover, ambient conditions and visibility, that may affect their willingness to use different structures to move under and over roads The guilds facilitate an understanding of why certain species have specific requirements and 'what works' for different types of species. Predator avoidance is a key factor for most wildlife. As different species have different detection and avoidance strategies, crossing structures must address the strategies of the target wildlife at a given location. In addition, some species are limited by their movement capacity (slow vs. fast-moving), by their mode of travel (ground, water, air), or by their need for consistent environmental conditions (e.g., some amphibians); these specific habitat requirements also need to be addressed. The type of preferred habitat that an animal lives in within an ecoregion also affects how they use a crossing. Populations of the same species may be more willing than others to use a crossing based on its similarity to the landscape it is placed in. A population's experience with humans and other factors can also affect how they use a crossing; where some wildlife populations may be adapted to human presence, for others it causes a fear or avoidance reaction. The Species Movement Guilds are based on generalizations across populations and provide broad guidance for application within the context of the landscape and specific situations at hand. The guilds were developed with careful review of published and grey literature in wildlife and transportation ecology as well as the author's and other colleagues combined experience with wildlife movement and roads across the U.S. and Canada; pertinent references are included in the discussion of each of guild in the following section.

The purpose of Species Movement Guilds classification scheme is to provide a user-friendly framework for transportation biologists to determine how well the movement needs of target species are accommodated by existing transportation infrastructure and whether post-construction improvements could improve wildlife passage at a given location. This process allows biologists to better understand the permeability of the transportation network for different types of species. Although the classification was designed specifically with regards to improving bridges, culverts and overpasses, it could also be applied to the design of shoulder and median barriers, fences and related roadway infrastructure. By combining an understanding the movement needs of each Species Movement Guild with the situational and structural attributes that render a structure functional for those guilds, biologists are better positioned to evaluate suitable enhancement options at a given location or, if no such option is available, advise the design for a new, effective wildlife crossing. Developed in collaboration with a colleague at the U.S. Forest Service, the Species Movement Guilds were compiled with reference to the best available research and monitoring information (including the concurrent monitoring project in Washington), and were further validated and refined during the field test of the structure evaluation system.

Further conditions for defining Species Movement Guilds included culvert and bridge minimum size requirements and structure characteristics such as substrate, cover, openness, ambient conditions, lighting, lines of sight, sound buffering, shape, approach conditions, amount of human use/development, etc. Typically, when designing passage structures the movement needs of multiple types of species must be addressed as opposed to a single species or guild. Intuitively, large structures may be designed to accommodate smaller species, whereas small culverts cannot accommodate larger wildlife species. However, the specific design characteristics required by each target Species Movement Guilds must be individually addressed; a larger structure will not automatically accommodate small animals if it does not provide appropriate cover or other necessary attributes. This species classification offers a useful mechanism for an initial assessment of needs and opportunities. In all cases additional analysis is required to determine the best options for accommodating multiple species or regional variations in species preferences due to the presence or lack of predators, human activity, resource availability or other considerations.

TABLE 1: Terrestrial Species Movement Guilds. A functional categorization of terrestrial wildlife based on body size, predator avoidance strategies, and species behavior relative to road infrastructure, traffic and crossing structure characteristics. Developed by the authors in collaboration with Sandra Jacobson, U.S. Forest Service.

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Attributes	Preferred Structures
Low Mobility Small Fauna (LMSF)	Invertebrates, frogs, toads, some salamanders, some ground insects	Small, slow-moving species that require specific ambient conditions (including possibly moisture and light) to survive and disperse. Some species in this group may take several generations to move across a structure. Completely enclosed structures may interfere with directional movements for some species that navigate by reference to celestial features.	Crossings must provide species-specific habitat and consistent outside environmental conditions throughout the entire structure, including natural substrate, light, temperature and moisture. Species in this category may be found adjacent to water, but probably prefer dry pathways or pathways without flowing water through culverts.	*Extensive bridges, wildlife overpasses, trench drains*
Moderate Mobility Small Fauna (MMSF)	Ground squirrels, shrews, rabbit, hare, chipmunk, vole, mice, skunk, raccoon, some salamanders, lizards, turtles, snakes, badger, marmot, weasel, pika, fox, marten, fisher, river otter, beaver, mink, muskrat, some ground birds	Small animals that are fairly adaptable to different types and sizes of structures. Almost all of these species are prey for larger species and require some hiding cover for protection. Some may require a natural substrate or moisture to survive in structures, and most prefer natural substrates.	Functional crossing structures include a variety of structure types and sizes. A non-submerged pathway is almost always preferred and usually required by species in this guild. They may also use structures with artificial substrate or ramps. Cover provided within larger structures with rocks, vegetation or smaller pipes is usable.	*Small, medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses*
Adaptive High Mobility Fauna (AHMF)	Black bear, bobcat, coyote, lynx	Medium-sized mammals that naturally use enclosed spaces for dens, and can tolerate a limited amount of enclosure in underpasses. Minimum crossing structure size is proportional to species body size.	Species in this group may use a variety of structure types and prefer to have suitable habitat directly adjacent to the structure entrances.	*Small, medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses*
High Openness High Mobility Carnivores (HOHMC)	Grizzly bear, mountain lion, wolf	Highly mobile species that prefer good visibility. Typically larger animals that have a larger minimum structure size requirement than Adaptive High Mobility Fauna. These species range widely across the landscape and may need to cross multiple highways.	Open structures that provide good visibility but can be tolerant of longer structures (>100'). Species in this group tend to prefer more open structures than Adaptive High Mobility Fauna but are more tolerant of enclosed structures than Very High Openness Fauna.	*Large bridge underpasses, extensive bridges, wildlife overpasses*

Species Movement Guild	Species Examples	Species Attributes	Preferred Passage Attributes	Preferred Structures
Adaptive Ungulates (AU)	Mule and white-tailed deer, moose, mountain goat	Medium and large-sized ungulates that require good visibility on a horizontal plane and a moderate amount of cover. These animals prefer a natural substrate and adjacent cover, but may also use concrete-bottomed culverts. Ungulates in this group use structures in approximate proportion to their body size (i.e., deer can use smaller structures than moose).	Passages that have good visibility within and around the structure and clear lines of sight from one end of a crossing structure to the other. Preferred structures are wider than they are tall and are less than 100' in length. Mule deer may prefer more open structures than white-tailed deer.	*Medium or large underpasses (culverts and bridges), extensive bridges, wildlife overpasses*
Very High Openness Fauna (VHOF)	Elk, pronghorn, bighorn sheep, open habitat grouse	Ungulates in this group are particularly wary of predators and require very wide vistas and clear lines of sight. They tend to prefer a moderate amount of hiding cover that does not infringe on their ability to detect or escape predators. Structure size is dictated primarily life history attributes such as predator avoidance or maneuverability.	Large passages with wide openings (at least 15') that are less than 100' long, excellent visibility within and around the structure, and clear lines of sight from one end of a crossing structure to the other. Bridge underpass structures with natural earthen side slopes are preferred to those with concrete or metal walls. Features that may encourage passage include a natural substrate, and noise and light contrast moderating features.	*Large culvert or bridge underpasses, extensive bridges, wildlife overpasses*
Arboreal Fauna (ArbF)	Flying squirrels, some bats, arboreal voles	Species that move primarily through the canopy rather than on the ground surface.	Features for these species provide a continuous canopy-level structure across the roadway.	*Treetop rope bridges, towers, or modified wire or metal structures.*
Aerial Fauna (AerF)	Songbirds, raptors, bats, flying insects (including butterflies)	Species whose primary mode of movement is flying.	Features for these species aim to divert flying species out of the path of traffic.	*Diversion poles, extensive bridges, wildlife overpasses*

2.2.1. Research Summary of Species Preferences and Behavior

This section provides an overview of each of the Species Movement Guilds and the research on individual species that informed the categorization scheme. For each guild, a discussion of the trends found in transportation ecology is presented and specific conditions preferred by different species are noted. This discussion is presented with the understanding that a given crossing may be constructed for suites of species rather than a single target species, in which case crossing designs should draw from the 'preferred characteristics' listed for the suite of species present at that site. There is no perfect crossing structure, as any structure is mitigation – at best, adequate compensation for the natural landscape connectivity that has been lost. As such, the potentially conflicting needs of multiple species must be balanced at any given site. Additional research and information sharing across states and countries will help to further improve crossing designs of the future.

2.2.1-1. Low Mobility Small Fauna

Members of this guild include small, slow-moving animals that require specific ambient conditions (for example, moisture or light) through the length of a crossing structure, such as frogs, toads, some salamanders, invertebrates and some ground insects. Structures for these species may be open at the top to permit moisture and light to enter the structure and to allow navigation with respect to celestial navigation. The structures may be enclosed as well, thus protecting the animals from road pollution and traffic noise. Some species in this guild may take several generations to move the length of a crossing structure, such as insects. Species in this category are found across the spectrum of natural areas including near water (such as frogs and salamanders), dry upland areas (toads and tortoises), and even those amphibians willing to travel over snow to breed, such as long-toed salamanders. As a result of this extreme diversity in preferences of areas of movement, crossings must provide species-specific habitat and consistent outside environmental conditions throughout the entire structure, including natural substrate, light, temperature and moisture. These structures could be small culverts, or large bridges that provide natural substrate beneath them for contiguous movement.

Specific Considerations for Amphibians and Reptiles

<u>Salamanders and Frogs</u>

The first amphibian crossings in the United States were a pair of salamander crossings placed under a road in Amherst, Massachusetts in 1987. These tunnels were placed 200 feet (61 m) apart and connected with a system of 12-inch (30.5 cm) high drift fences to direct the salamanders towards the tunnels. Jackson (1996) found that salamanders need light to see inside the tunnel, and once artificial light was provided, the time it took for salamanders to enter and pass through the tunnels was dramatically reduced. Salamanders need moisture in their passages, and crossings designed for these species should include some mechanism for allowing rain to enter and moisten the substrate within the underpass. Jackson (1996) suggests when considering more than two lane highways for tunnels, take into account animals freezing along the way and either minimize the length of the passage, or provide island-stop over habitat that could serve as half-way points for migrating amphibians.

A typical amphibian crossing is circular or rectangular; generally less than 1.6 feet (0.5 m) in cross section; as short as possible; and with a floor lined with a natural soil substrate (Aresco 2005, Jackson 2003). Specific guidelines for designing amphibian crossings include the following considerations:

- The tunnel should be open at top and fitted with iron grate flush with road surface to allow ample light, rain, and air to circulate (Jackson 2003). Brehm (1989) further notes that grated passages play an important role in providing aeration and equilibrium of ambient temperatures and moisture conditions.
- Because some amphibians and reptiles use olfactory cues to assist them in their movements, Jochimsen et al. (2004) suggest allowing for a layer of detritus and leafy substrate to remain undisturbed along the length of passages.
- Tunnels should be situated so that they can be easily accessed and not prone to flooding (Puky and Vogel 2004).
- Maintenance of amphibian tunnels is also extremely important for functional crossings; tunnels should be cleaned on an annual basis before the start of the migration period (Puky and Vogel 2004).
- Wing walls should angle out from each end of tunnel at approximately 45 degrees (Jackson 2003) and continue outward as guide fencing. This fencing can be plastic (polythene mesh) or concrete (Grillo et al. 2010), or even fashioned from metal guard rails stacked vertically.
- The height of the vertical guide walls can vary from 18 inches (45.7 cm) to over 3.3 feet (1 m; Fig. 7; Aresco 2005, Jackson 2003). The length should extend from the wing walls for 100-300 feet (30-90 m) on both sides of the road. The tops of these walls should be angled away from the road to prevent climbing organisms from getting over the fence. Jackson and Tyning (1989) also suggest that the drift fences should be sunk into the ground 2.5-4 inches (6-10 cm; Figure 8). Some animals do not follow fences. Jackson and Tyning (1989) found that wood

Figure 7. Amphibian and reptile barrier wall at Paynes Prairie State Preserve, along US 441 in Gainesville, Florida © P. Cramer

Figure 8. Drift fencing to funnel turtles under the highway to get to other side of Lake Jackson, Tallahassee, FL © P. Cramer

frogs have been hesitant to move along the fencing.

- Crossing structures should be spaced within 200 feet (61 m) of one another (Jackson 2003); Puky and Vogel (2004) found a maximum spacing distance of 260-328 feet (80-100 m) to be adequate, but recommend determining the spacing between crossing structure on the basis of the migration radius of the target species under normal conditions.
- Locate crossings in the center of migration routes rather than at the edges. To find these migration routes, the species need to be studied for at least two years because routes vary from year to year (Puky and Vogel 2004).
- The authors conclude that close cooperation between engineers and biologists specializing in amphibians is of utmost importance to finding mutually acceptable solutions (Puky and Vogel 2004).

Drainage culverts and culverts designed to allow the flow of water can be modified to pass amphibians and reptiles via the installation of shelves or floating docks inside the culvert (Jochimsen et al. 2004). Jackson (1999) suggests channelizing the water through the culvert to create an extended bank area, although this action should be conducted only with careful consideration of aquatic connectivity needs through the culvert. Dry culverts can be enhanced with the placement of natural substrate inside the culvert to provide a suitable movement surface for amphibians. The addition of cover in the form of vegetation, logs or rocks inside the culvert can also improve conditions for these prey species.

While keeping the top of a culvert open allows for moisture, light, and a view of the night sky, it also allows for road runoff to enter the crossing. This may expose the moving animals to heavy metals such as copper, zinc, and lead, as well as petroleum derivatives. Further research is needed that helps in the design of crossings for this small fauna group. Perhaps multi-chamber designs could be created where outside chambers of a three-chambered culvert would catch the pollutants running off the road, while the middle third chamber is open and aerated but free of road runoff. Another idea would be to find a way to deliver moisture to the culvert from more pure sources outside of the road-right-of way, thus avoiding the need to deliver moisture from the road.

For further information on mitigation solutions for wildlife at locations with road-stream crossings, readers may reference a recent publication from Massachusetts Department of Transportation (Massachusetts Department of Transportation 2010), which offers very instructive recommendations on placing new structures and enhancing older ones to accommodate amphibians and aquatic species in a stream environment.

BOX 1: Paynes Prairie Ecopassages

Some of the most successful amphibian (and reptile) crossing structures and fencing are located in Florida. The Paynes Prairie ecopassages (concrete box culverts) and accompanying concrete wall have worked very successfully (Fig. 9; Dodd et al. 2004), with a 93% reduction in total numbers of animals killed one year post-construction. The wall which kept the animals off the road is a one meter high concrete wall with a 6 inch (15.24 cm) lip that faces toward the wild lands away from the road. The concrete is composed of a very smooth mix, so it would be difficult for animals to climb up. There are 8 box culverts along 2 miles of a four lane divided highway. The culverts are approximately 8 feet by 8 feet (2.4x2.4 m), but with natural sedimentation in the culverts, the heights have decreased somewhat over time. At all times there are at least two box culverts with running water, and two culverts at the edges of the wet prairie that are dry. The remaining culverts vary in water depth according to conditions. The greatest weakness of this system at this time is the lack of regular maintenance to clear vegetation growing near the concrete wall. Because plants can grow up and over the wall, tree frogs and other climbing species have been able to access the roadway in this manner. A United States Geological Survey (USGS) website is dedicated to the project (United States Geological Survey 2011).

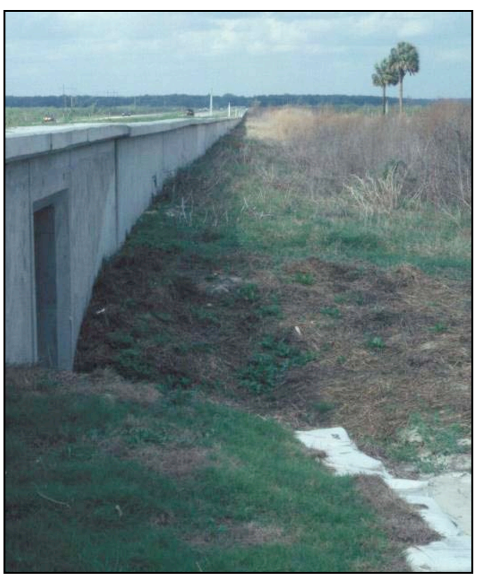


Figure 9. Paynes Prairie Ecopassage and amphibian and reptile wall, shortly after construction © P. Cramer

Turtles, Tortoises, Snakes and Lizards

Many of the considerations for amphibians are identical for reptiles. The Paynes Prairie ecopassages mentioned above for amphibians have worked for lizards, alligators and snakes, but no turtles were recorded using the culverts. However, in a study of painted turtle movement Jackson and Marchand (1998) found that a 2'x2'x20'[1] (6x6x37 m) tunnel made of wood with 131 feet (40 m) of drift fence at both ends was successfully used by painted turtles, though no road was involved in this study. In this study, the authors caution that clear lines of sight along the drift fencing as well as at the tunnel entrances were an important variable for successful through-passage.

The more recent Lake Jackson crossings and ecopassages along Lake Jackson north of Tallahassee, Florida were installed in 2010. Prior to the installation of the wall and culverts for turtle movement, Aresco (2005) was able to temporarily reduce the high mortality of moving turtles with a drift fence to an existing culvert, and conducted monitoring of the stretch of road for 44 months. A website (Aresco 2011) gives a thorough review of the entire process of identifying a deadly stretch of road for turtles, and raising public awareness and agency support, and finally a mitigation system that includes culverts and a concrete wall like those along Paynes Prairie, Florida (see Box 1).

Overall, research indicates that reptilian species preferences for crossing types and placement are varied among species (Jochimsen et al. 2004, Little et al. 2002), underscoring the importance of local research on the target species of interest to inform the design of mitigation solutions (Woltz et al. 2008). In Portland Oregon, the Port of Portland Authority built turtle culverts for painted turtles, which, although not scientifically studied, appear to work (Figs. 10 & 11).

Figure 10. Painted turtle using new turtle crossing culvert in Portland ©Port of Portland

Figure 11. Turtle culvert, wall, and grate ©Port of Portland

[1] All structure dimensions in this document use the format: Height-by-Span-by Length; or if structure length is not being discussed, simply: Height-by-Span.

For further reference, see Jochimsen et al.(2004), which provides an overview of how various structural and ecosystem characteristics effect structure effectiveness at moving amphibians and reptiles. In addition, the Minnesota Department of Natural Resources recently updated a publication on designs and practices for the repair and reconstruction of culverts, bridges, and storm water outfalls (Leete 2010). The document is particularly useful in the design of wildlife benches and curbs for animals of all sizes and shapes, and includes recommendations for using biodegradable materials to replace the use of nylon mesh for erosion control, which is known to trap small animals, such as snakes, frogs, toads, turtles, and ducklings.

2.2.1-2. Moderate Mobility Small Fauna

Moderate Mobility Small Fauna are small animals such as ground squirrels, rabbits, voles, raccoons, snakes, badgers, marmots and weasels that are fairly adaptable to a variety of structure types and sizes (Fig. 12). Members of this guild are typically preyed upon by larger species and, therefore, require protective cover through a structure or, at minimum, at the approaches to a structure (Foresman 2004). Such cover may be vegetative, wood debris, rock, or even artificial cover. While some members of this guild may require a natural substrate through a culvert, others may be tolerant of an artificial surface. Most of the species in this guild prefer a non-submerged pathway through a crossing structure. If there is any flow of water through a structure, passage can be greatly increased with wildlife shelves. Twelve species of mammals that are members of the carnivore and rodent families have been documented using artificial benches created by placing shelves in these culverts (Foresman 2004).

Traffic volume and traffic noise at crossing sites can have mixed effects on these species. Clevenger et al. (2001) found that as traffic volume increased, marten, weasel, snowshoe hare, and red squirrel use of wildlife crossing culverts increased. This could be due to the fact the animals could not find breaks in the traffic that would allow them to cross the road at-grade.

Specific Considerations

<u>Rodents</u>

Foresman (2004) documented heavy use of culverts by rodents in Montana along U.S. Highway 93. Deer mice, meadow voles, red squirrel, muskrat, ground squirrel, shrews, yellow-bellied marmot, mountain cottontail, wood rat, porcupine, and fox squirrel were photographed in corrugated steel culverts ranging from 3-12 feet (0.9 m to 3.75 m) in diameter. In Vermont, Bellis

Figure 12. Mountain cottontail using a pipe culvert in Colorado under I-70 © Center for Native Ecosystems, ECO-resolutions, LLC & CDOT

(2008) live-trapped small mammals on both sides of two wildlife bridge underpasses. In two summers of trapping the only animals he could document using the crossings were deer mice species (*n*=13). Voles, chipmunks, jumping mice, red squirrels, weasels, and ermine were all captured on one side of the road but never recaptured on the opposite side. These structures had recently been constructed and there was little natural vegetation within 50 feet (15.2 m) of the bridges. Bellis noted in his thesis work conducted by McDonald and St. Clair (2004) that found that small mammals, including three species also included in Bellis' Vermont study, had much higher success moving through smaller than larger crossing structures, which they attributed to greater overhead cover in the smaller structures. McDonald and St. Clair (2004) also mention that a lack of natural vegetation at crossing structure limited use among small mammals.

<u>Small Carnivores</u>

Clevenger et al. (2001) found that weasels, *Mustela ermine* and *M. frenata,* preferred culverts that are higher, but culvert use was negatively correlated with greater culvert openness, apparently preferring high and narrow culverts. In the same Banff study, pine martens preferred culverts with low clearance and high openness ratios, meaning they preferred short and wide culverts. Weasels' use of culverts was also positively correlated with the amount of vegetative cover. Badgers have been recorded using culverts, especially in British Columbia (Klafki 2002, Newhouse and Kinley 2002), which mimic their natural burrows on the landscape (Fig. 13).

Overall, crossings that would promote movement of Moderate Mobility Small Fauna need to have vegetation right up to the crossing structure entrance; be small in size relative to other wildlife crossings; be free of water year round or a shelf structure placed to facilitate small and meso mammal movement (Fig. 14); include a tube built in below the shelf for voles; and be less than 300 feet (91.4 m) in length. All the culverts in the studies mentioned are 200 feet (61 m) or less in length as the animal traverses under the road.

Figure 13. Badgers in culvert in British Columbia © S. Towers

Figure 14. Ermine, or short tailed weasel using wildlife shelf in culvert under US 93, Montana © K. Foresman

2.2.1-3. Adaptive High Mobility Fauna

This guild includes medium-sized mammals that are naturally accustomed to enclosed spaces for denning and are tolerant, to a limited degree, of a more enclosed situation in an underpass. Members of this guild include black bear, bobcat, coyote, and Canada lynx. Adaptive High Mobility Fauna may adapt to a variety of structure types, so long as a minimum size requirement is met, proportional to the size of the animal.

Specific Considerations

Black Bear

Black bear have demonstrated an ability to use wildlife crossings in Florida (Foster and Humphrey 1995), North Carolina (McCollister and van Manen 2010), Vermont, Colorado (Singer et al. 2011), Utah (Cramer 2011), Montana (Foresman 2004, and Cramer et al. 2011), Washington (this study), and Alberta, Canada (Clevenger and Waltho 2005). Overall, scientists report black bear will use bridge wildlife underpasses and culverts (McCollister and van Manen 2010, Clevenger and Waltho 2005, Cramer et al. 2011, Singer et al. 2011). Clevenger and Waltho (2005) found black bear tended to use crossing structures that were constricted in space. In Montana, black bear have been photographed using a variety of structures. While Foresman (2004) photographed a black bear using a culvert 3.1 feet (0.95 m) in height, Dr. Cramer's current study on the same stretch of US 93 has revealed black bear using bridge crossings more often than culvert crossings. In Washington, the authors of this report documented 30 black bear passages through a pair of 12'x29'x120-144' (3.7x8.8x37-44 m) arch culverts under I-90 (Fig. 15). Only one of the 31 bear approaches resulted in a repel action. It appears the black bear in the North Bend area of Washington have adapted to this culvert. From the wide geographic span of photos of black bear using structures, it is apparent that they are a highly adaptable species and will use structures they can fit through and feel safe entering. From the data collected in the habitat area around the North Bend, Washington culvert, it also appears that vegetative cover is important to Washington black bears.

Figure 15. Black bear cubs passing through culvert behind mom, under I-90 Washington © P. Cramer, J. Kintsch & WSDOT

Coyote

The coyote is a wide ranging habitat generalist that is known to be quite tolerant of human activity, and is one of the most adaptable and widespread carnivores in North America (Fitzgerald et al.1994). Coyotes almost certainly use culverts and bridges in every state and province in the U.S. and Canada. Coyotes are tolerant of smaller spaces, such as drainage culverts, and can also adapt to bridge crossings. They are also known to cross at-grade over roads. Clevenger et al. (2001) and Foresman (2004) documented multiple coyote passages in culverts ranging from 3 feet (~1 m) up to 12 feet (3.7 m) high. Alternatively, Haas (2000) found coyote use of underpasses in California increased with underpass openness, and that fencing and roadway dividers (shoulder and median barriers) were most effective in encouraging coyote use of underpasses. Lyren (2000) found the same population of coyotes experienced significantly higher mortality by vehicles in areas with no wildlife fencing as compared to areas with wildlife fencing. The volume of traffic appears to also affect coyote use of structures. Lyren (2000) studied the same underpasses Haas (2000) studied in California and found the frequency of underpass use by coyotes appeared to be suppressed by traffic volume. Clevenger et al. (2001) also found that traffic volume was the most important predictive factor in coyote use of culverts in Alberta, with their use negatively correlated with traffic. These findings may indicate an aversion to traffic noise and possible avoidance of human activity (due to persecution).

In Washington, coyotes were photographed in this study at both bridge and culvert structures (Fig. 16). At a large culvert under I-90 near North Bend, coyotes were photographed at the entrance 19 times. They appeared to repel from the culvert on three occasions, and paralleled the structure at least four times. This is one of the highest volume roads in Washington and it is not known if the traffic volume affected the coyotes' use of this and other monitored structures.

Figure 16. Coyote using culvert under I-90, Washington © P. Cramer, J. Kintsch & WSDOT

In general, structures for coyote passage can be quite variable, but coyotes are a wary predator and sometimes behave like a prey species – in part due to the continued hunting pressures from humans in every state – and may be hesitant to use crossing structures. The presence of native vegetation cover at crossing structure entrances (positive correlation), human activity (probable negative correlation), traffic volumes/noise (negative correlation), and the presence of guide fencing (positive correlation) may all affect a coyote's willingness to use a crossing structure.

Bobcats

Bobcats have been documented using structures in Montana (Cramer et al. 2011, and a study underway on US 93 North of Missoula by the Salish Kootenai Tribe and Western Transportation Institute), Colorado (Singer et al.2011), California (Haas 2000, Lyren 2000, Ng et al. 2004), Florida (Foster and Humprey 1995, Dodd et al. 2004), Vermont (Bellis 2008) and in Washington in this study, among others. A common theme among bobcat and wildlife crossing studies was that bobcats were documented with a preference for crossing roads at-grade, even in places where there are wildlife crossing culverts and bridges present (Bellis 2008, Cain et al. 2003, Haas 2000, Lyren 2000, Ng et al. 2004), often becoming victims of vehicular collisions. Cain et al. (2003) also found that bobcats crossed roads most frequently in areas where distance between dense vegetation was shortest. When they do use structures, they appear to prefer larger structures over more confined culverts, although monitoring in Colorado captured photographs of bobcats using pipe culverts as small as 7.4 feet (2.25 m) in diameter, including one partially sediment-filled pipe, and as large as an open span bridge (Fig. 17; Singer et al.2011). Cain et al. (2003) found bobcat exhibited a preference for structures with high openness ratios. In Florida Foster and Humphrey (1995) recorded some of the first monitoring pictures of bobcats, which were under pairs of bridges on I-75. In this Washington study, bobcats were recorded only at the large arch culvert under I-90 near North Bend. There were three bobcat observations and all appeared to pass through the culvert. In Washington, bobcats may be more prone to using crossing in areas with abundant natural vegetation cover on both sides of the road – as is present at North Bend crossing – and with low levels of human activity (Fig. 18).

Figure 17. Bobcat using pipe culvert under I-70, Colorado © Center for Native Ecosystems, ECO-resolutions, LLC & CDOT.

Figure 18. Bobcat using large arch culvert under I-90, Washington © P. Cramer, J. Kintsch & WSDOT.

Lynx

Low population densities, large home ranges and wide-ranging movements across the landscape have made lynx particularly difficult study subjects; consequently, few studies have documented lynx use of crossing structures. Over the course of three years of monitoring at seven different sites across Colorado, researchers did not document a single lynx using the structures, which included two pipe culverts and five box culverts (Crooks et al. 2008). Lynx have been documented using wildlife underpasses and overpasses in Banff, Canada, but lynx are not common around Banff and their use of the structures has been only rarely captured. As of yet, researchers cannot confirm whether lynx will readily use crossing structures in the western United States (Huijser and Paul 2008).

2.2.1-4. High Openness High Mobility Carnivores

The carnivores of this guild, including grizzly bear, wolf and puma, prefer large structures with good visibility. Because of their larger body sizes, members of this guild have a larger minimum structure size requirement than Adaptive High Mobility Fauna such as black bear and coyotes. Species in this group tend to prefer more open structures than Adaptive High Mobility Fauna, but are more tolerant of structures longer than 100 feet (30.5 m) or enclosed structures than members of the Very High Openness Fauna Guild, such as elk.

Few studies have analyzed how the group of carnivores encompassed by this guild use wildlife crossings as a whole. Clevenger and Waltho (2000) analyzed carnivore movement through 11 wildlife underpasses in Banff National Park in Alberta, Canada for 35 months and were able to make some generalizations. They found that grizzly bear, black bear, wolf, and puma use of crossings was more influenced by human activities than by structure variables. The most significant attribute influencing these species' use of the wildlife crossings was underpass distance to town site (positively correlated), followed by human activities such as hiking and human use of the site and horseback riding (negatively correlated). They found the landscape and structure variables were the least significant attributes affecting how the carnivores used the structures. Individual species preferences have been analyzed in more detail in other studies, as described below.

Specific Considerations

Puma (Mountain Lion)

Pumas are habitat generalists, but as highly specialized ambush predators they require good cover or complex terrain for concealment (Sweanor et al.2000). Exurban development and recreational activity in puma habitat in recent decades has led to an increase in human conflicts with this species. Beier (1995) found that while pumas avoided substantially developed areas and the associated noise, lighting, and presence of domestic dogs, they readily used areas with heavily used recreational trails.

Gloyne and Clevenger (2001) reported on puma use of 22 crossing structures in Banff National Park in Alberta. They found a significant positive correlation between passages made by puma through the structures and the passages made by mule deer and white-tailed deer. Contrary to the Clevenger and Waltho (2000) publication just one year earlier for the same study site, they found no correlation between puma and human use of the wildlife crossings. Puma's use of open span bridged underpasses was more than expected. Bridge underpasses spanning creek drainages were used in proportion to their availability, while all other crossing types were used significantly less than expected. The crossings with the highest number of puma passages were those situated close to high quality puma habitat. The general take home message from this study was that puma tended to use underpasses more than overpass structures. Clevenger and Waltho (2005) in a later study of the Banff Crossing structures found puma favored more constricted spaces for crossings. The analysis in this study also found that distance to cover was the most important landscape attribute for successful puma usage of crossing structures, where the greater the distance to cover, the lower the likelihood of successful passage.

Figure 19. Puma (mountain lion) using a box culvert under I-70 in Utah © P. Cramer

Studies in Utah (Cramer 2011) and Montana (Cramer et al. 2011) have recorded puma presence approximately a dozen times. They have shown to be highly adaptable and have been photographed crossing at-grade over U.S. 93 in Montana, and under Interstates in Utah using box culverts (Fig. 19) and bridges and repeatedly over an interstate on a narrow wildlife overpass. Although there is not enough data at this time for statistical analyses in these studies, it appears puma prefer to cross roads in areas with little human development.

<u>Other High Openness High Mobility Carnivores</u>

There are few studies that document wolf or grizzly bear use of wildlife passages. Clevenger and Waltho (2005) found grizzly bear and wolf tended to use crossings that were high, wide, and short in length. Given their hesitancy to use crossings, in large part due to their cautious nature with humans, this study is the only one that defines these species preferences and would be the best recommendation for crossing structures that pass these species at this time.

2.2.1-5. Adaptive Ungulates

All ungulates in North America have been recorded using wildlife crossing structures. However, several of these species are significantly more adaptable to a variety of wildlife crossing structures than others – these are the Adaptive Ungulates. This guild includes white-tailed deer, mule deer, moose, and mountain goat. These are species that have minimum requirements for suitable crossing structures, but are not as hesitant to enter the enclosed spaces of culverts or even bridges, as are species in the guild Very High Openness Fauna.

Specific Considerations

Mule deer

Mule deer (including black-tailed deer, a subspecies of mule deer) is the primary deer species of interest with regards to wildlife-road conflicts in Washington, and is the species this report will focus on most intensely. White-tailed deer are also present in Washington, particularly in the eastern portion of the state. Of the 100-plus wildlife passages nationwide that have been specifically designed for mule deer, nearly all have successfully passed mule deer (Bissonette and Cramer 2008). Mule deer and white-tailed deer are adaptive species and over time can learn to use bridges and culverts as passageways, particularly if eight-foot high guide fencing is present. White-tailed deer have proven to be very adaptive to transportation structures across the U.S. and the preferences for mule deer below can generally apply to them as well.

Mule Deer and Culverts

The first mule deer wildlife passage study was in Colorado at a box culvert under Interstate 70 (Reed et al. 1975). This 10’x10’x100’ (3x3x30.5 m) box culvert passes some mule deer, but the long, narrow culvert may have a high repel rate (Singer et al. 2011) and in the first years after the culvert was built only a portion of the herd used the culvert in their seasonal migration route, leaving many animals unable to reach their wintering grounds. Subsequent studies (Ford 1980, Gordon et al. 2003, Gordon and Anderson 2003, Rosa 2006) demonstrated that mule deer were willing to use a range of culvert shapes and sizes. Gordon and Anderson (2003) implemented a design in Wyoming where the dimensions of a concrete box culvert under a two-lane road could be manipulated to study the point at which more deer were repelled away from the culvert that used it. The smallest functional dimension for mule deer in this study was 12’x20’ (3.7x6 m) under a two lane road where the culvert was 60 feet (18 m) in length. As a result, these dimensions have become the minimum standard for the design of crossing structures for large herds of mule deer rather than just occasional individual animals. Ongoing monitoring of six new similarly-sized culverts connected with wildlife exclusion fencing along the same Wyoming roadway have documented over 13,000 successful mule deer crossings along this migration corridor between October 1 through December 31, 2010 (Sawyer and LeBeau 2011).

Ongoing research in Utah (Cramer 2011) is documenting successful as well as attempted passage at three differently-sized corrugated steel plate culverts (all designed as wildlife crossings), eight concrete box culverts (one designed as a wildlife crossing), as well as three bridges designed specifically for wildlife and four additional existing bridges. While the study is not complete, it appears that a sense of structure openness for culverts, especially, is a very important characteristic for mule deer. The study further demonstrates that longer culverts (greater than 120 feet long [36.6 m]) have higher repel rates (i.e., which are when animals approach a structure and then turn away) than the shorter culverts (ranging in length from 65 to 120 feet long [19.8-36.6 m]). The long culverts pass beneath four lane highways, while the shorter culverts path beneath two-lane roads or two lanes of highway with an open median. Even along interstates, it appears that paired culverts with separate structures for the opposing traffic lanes, and an open median can accommodate mule deer fairly successfully. For example, along I-15 there are two sets of corrugated steel culverts that are shorter (65-75' long [19.8-22.9 m]) and larger (17-20' high [5.2-6 m]) than the other culverts in the study (Fig. 20). These culverts have low rates of repellence (5-6%) compared to rates of repellence of 20 to 35 percent for longer culverts. The study also demonstrated that concrete box culverts 200 feet (61 m) or longer along Interstates 70 and 15 did not function as wildlife crossings for mule deer if there was no wildlife fencing present. Further research will help determine whether deer can be encouraged to use such long structures in areas where wildlife exclusion fencing has recently been placed.

Figure 20. Mule deer moving through culvert under US 91 in Utah © P. Cramer

It appears that mule deer are willing to traverse under two lane roads through culverts that are approximate 100 feet (30.5 m) long and a variety of heights and widths, as long as the height is a minimum of 10 feet (3 m) and the width 20 feet (6 m; Sawyer and LeBeau 2011), with some varying conditions acceptable. When culverts are longer than the width of two lanes of traffic, repellence rates for mule deer increase to 10 to 50 percent of approaches. Based on these research studies, it is recommended that culvert crossing structures be less than 120 feet (37 m) and most definitely less than 200 feet (61 m) for passing species in the Adaptive Ungulates Guild. Minimizing culvert length as much as possible is recommended to accommodate the majority of mule deer that approach a culvert. If a culvert must traverse more than two lanes, then opening up the culvert by increasing the height and, in particular, the width of the culvert at eye-level (for a mule deer) is recommended to the extent possible. In addition, two separate culverts placed under opposing lanes of traffic with an open median between the two culverts can create a more appealing situation for mule deer (as well as a number of other species in this and other guilds) than a single, long culvert (Fig. 21).

Figure 21. Black-tailed deer doe and fawns crossing under four lanes of I-90 through a pair of double box culverts, Washington © P. Cramer, J. Kintsch & WSDOT

Mule Deer and Bridges

Bridges of all kinds and sizes have been shown to function for mule deer. Mule deer have been documented traversing under roads with two to four lanes with span bridges in Idaho (C. Class, personal communication), Utah (Cramer 2011, Rosa 2004), Wyoming (Sawyer and Rudd 2005), Arizona (Dodd et al. 2007b), California (Ford 1980), Colorado (Barnum 2003, Singer et al. 2011), Montana (Cramer et al. 2011) and Washington (this study). The rate of repellence is often not reported in studies or could not be measured. In Utah, rates of repellence at bridges that accommodate two to four lane highways ranges from 2.3 to 20% (Cramer 2011). In the Utah study the higher rates of repellence were related to multiple factors such as structure dimensions, human activity, the presence of livestock fencing tied to the structure base which is hard for young deer to negotiate, and animals still unaccustomed to a new structure during the first year of monitoring.

Figure 22. Mule deer using area under the Cle Elum bridge along I-90 © P. Cramer, J. Kintsch & WSDOT

The combined research suggests that any bridge that is a minimum of 10 feet (3 m) high and less than 100 feet long (30.5 m) as the animal traverses under the road has had success in passing hundreds of animals. There are few to no studies of mule deer using bridges that are over 100 feet in length under the lanes of traffic. This is because often, when there are greater than two lanes, opposing traffic is accommodated on two separate bridges or culverts with an open median. In Utah, Utah DOT has been able to accommodate four and five lanes of traffic on bridges less than 100 feet in length as the animals traverse under the road. In

Washington, the Cle Elum River Bridge along I-90 near the WSDOT Bullfrog Facility (milepost 79) is a perfect example of two low height (less than 10 feet [3 m] at the spots where mule deer cross under) bridges accommodating two to three lanes of traffic each, with an open median are sufficient for deer to adapt to using (Fig. 22; see monitoring report, Appendix D).

Mule Deer and Overpasses

Overpasses that have passed mule deer in the United States exist in Utah, Montana, and Nevada. Constructed in 1975, the Utah passage is the oldest wildlife overpass in North America. Each of a pair of bridges measures 210 feet (64 m) long by 22 feet (6.7 m) wide as they cross over I-15. More than 700 successful mule deer pass have been recorded over the first 18 months of monitoring (Fig. 23; Cramer 2011).

In 2009 in Montana, and 2010 in Nevada, pre-fabricated arch culverts were built around the two lanes of US 93 and dirt was filled over the culverts so wildlife could move over the traffic on wildlife overpasses approximately 100 feet (30.5 m) wide, in both states. Mule deer began using the Nevada overpass within days of completion (L. Bellis personal communication), while in Montana they were using it within weeks (P. Basting personal communication). Culvert overpasses such as these provide a cost-effective alternative (less than 2 million dollars) to wildlife bridges in areas where tunneling traffic is a viable option.

In addition to the research on different types of crossing structures, numerous studies have shown that 8-feet (2.4 m) high wildlife exclusion fencing is an important mechanism for boosting passage rates, preventing at-grade crossings, and helping animals to adapt to the crossing structures (Clevenger et al. 2002, Cramer 2011, Dodd et al. 2009). Wildlife fencing to guide deer towards a structure is recommended for all crossing structures, regardless of type.

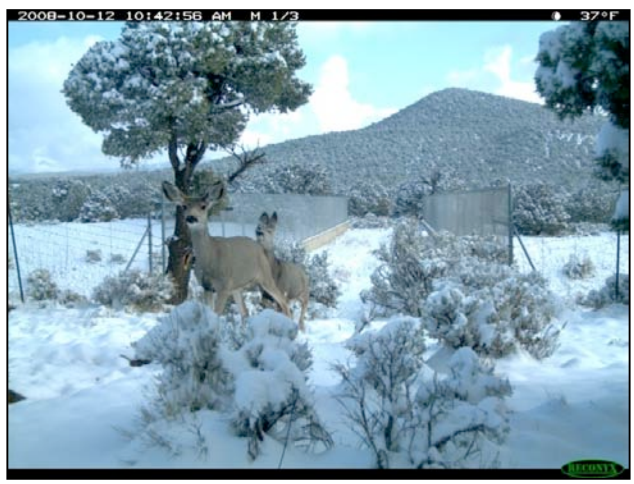


Figure 23. Mule deer using overpass over I-15, Utah © P. Cramer

Moose

Moose exhibit an amazing ability to adapt to small structures. Given their restricted range in the United States, few states have experience in accommodating moose in underpasses. In Utah, moose have been documented using 10’x17’ x165’ (3x5x50 m) corrugated steel culverts in the northern mountains (Fig. 24; Cramer 2011). Sawyer and LeBeau (2011) have similarly reported moose use of culverts measuring 10’x20’x60’ (3x6x18 m) in Wyoming. While this is not the recommended size of structures built for moose, populations have adapted to culverts that have been in place for years. It is believed moose will pass readily under bridges, though

Figure 24. Moose using culvert under US 91 in Utah
© P. Cramer

there is little documented evidence of such movements and few monitoring studies have targeted or included the study of moose passage. An exception is an Alaska study, which documented moose movement under a specifically designed bridge crossing with a minimum passage height of 10.5 feet (3.2 m) along the length of the bridge and 9-foot (2.7 m) high guide fencing (McDonald 1991).

Mountain Goats

Mountain goats have shown a willingness to pass under bridges in Montana, just outside of Glacier National Park (Singer and Doherty 1985). This study is the only study known to the authors that documents mountain goat movements through structures explicitly built for them. There is no known research or anecdotal information documenting mountain goats passage through culverts, but there is little to suggest that herds of mountain goats would adapt to moving through culverts.

2.2.1-6. Very High Openness Fauna

Unlike the Adaptive Ungulates Guild, members of the Very High Openness Fauna Guild are particularly wary of predators and require very wide vistas and clear lines of sight through a crossing structure. They tend to prefer a moderate amount of cover at the structure approaches or even inside the structure; however such cover must not infringe upon their ability to detect or escape from potential predators. While largely composed of ungulate species, including elk, bighorn sheep and pronghorn, other predator-wary species, such as grouse, are also included in this guild.

Specific Considerations

Elk

Elk have proven to be very cautious with regards to their willingness to pass through bridges or culverts. In over 35 years of monitoring wildlife crossings in studies across the United States, elk have consistently shown themselves to be

Figure 25. Elk repelling from a long box culvert under I-70 in Utah © P. Cramer

extremely wary of using culverts of all shapes and sizes as crossings (Fig. 25). Regular use of box culverts by elk (a minimum of dozens of passages per year) has been documented at only one location in the United States, along US Highway 30 through Nugget Canyon in Wyoming (Sawyer and Le Beau 2011). Elk use of box culverts at other locations has been largely incidental, with less than five animals per occurrence (e.g., Singer et al. 2011). Prescriptions for wildlife crossings for elk should always involve a bridge. Elk have shown a willingness to use bridged wildlife crossings in Arizona (Dodd et al. 2007a), Utah (Cramer 2011, Rosa 2006), Wyoming (Sawyer and Rudd 2005) Idaho (C. Class personal communication), Colorado (Singer et al. 2011) and Washington (this study). In monitoring conducted for this study, elk showed a willingness to move under paired bridges accommodating I-90 at the Cle Elum and Snoqualmie Rivers. The Cle Elum Bridge is 11 feet (3.35 m) high at the locations elk were photographed grazing under the bridge. The Snoqualmie River bridge is 6.8 feet (2 m) high where elk were photographed traversing under the bridge. In this study, elk exhibited a preference for structures that are wide (over 65 feet [19.8 m]) across from side to side, giving a feeling of openness despite the seemingly low height of the structure. In Arizona, Dodd et al. (2007) found that the openness of the area under the bridge is an important factor influencing elk use of structures. This feeling of openness can be enhanced by angled natural substrate support slopes, as opposed to vertical walls. In the Arizona study, a pair of bridges a few hundred feet apart and almost identical in construction except for the abutment slopes had dramatically different elk usage rates. The structure with concrete walled sides produced significantly higher rates of repellence than the adjacent structure with sloped earthen sides. Dodd et al. (2007) suggest all bridged wildlife crossings include natural 2:1 slopes under the bridges rather than concrete materials.

Elk appear to be highly willing to use two overpass structures in Banff National Park in Alberta, Canada, where monitoring has documented elk passage numbers in the hundreds to thousands (Clevenger and Waltho 2005). Elsewhere, elk have not been documented in large numbers using overpasses, though, notably, of the handful of wildlife overpasses located in North America, only a few are located in elk habitat. In Utah, elk have been documented using the state's only overpass on only 12 occasions in two years. This overpass is composed of two bridges, each just 21 feet (6.4 m) wide and 200 feet (61 m) long, with a natural median above the level of traffic. All of these passes were made by bull elk. No females have been documented using this structure in over two years of monitoring, even though it has been in place for over 30 years and has ample tree cover at the entrances and in the median. The limiting factor may well be the narrow nature of the overpass.

An overarching guideline for evaluating existing structures for elk passage is to keep structures as open as possible (Fig. 26). The span of a structure as an elk crosses needs to be much wider than it is tall, as exhibited by the bridges structures along I-90 in this Washington study. Fencing elk to existing culverts may force individual elk through those culverts, but repeatedly across the western states, herds of elk have refused to use such structures. Bridges are the preferred option for elk passage.

Figure 26. E Bull elk moving under arched wildlife crossings under I-70, Utah © P. Cramer

<u>Pronghorn</u>

Pronghorn are notoriously wary animals and are perhaps the most difficult large mammal for which to design functional wildlife crossings. In a review of pronghorn movements near roads, Sawyer and Rudd (2005) concluded that either very high and wide bridges or overpasses are suitable structures for pronghorn passage. Little research has been conducted on the crossing features influencing pronghorn passage. According to Sawyer and LeBeau (2011), "U.S. Highway 30 in Nugget Canyon in Wyoming may be the only place where pronghorn have been documented using crossing structures (approximately 12 occurrences)". In this herd, it appears pronghorn learned to use the passage by following mule deer through the structure. Pronghorn overpasses are planned for the Trappers' Point area along US 189 near Pinedale, Wyoming.

<u>Bighorn Sheep</u>

Bighorn sheep have been studied only in Arizona to ascertain their preferences for crossings. Bristow and Crabb (2008) used radio collars and monitoring cameras to evaluate the effectiveness of three existing bridged underpasses for movement of desert bighorn sheep along Arizona's SR 68. In 25 successful crossing events, only rams used the structures. No marked ewes used the underpasses or crossed over the road at grade. In a separate study along US 93 in Arizona, several bighorn rams were documented using bridged underpasses and ewes and rams crossed across the road at grade (McKinney and Smith 2006). The authors of this study determined that the overpasses were necessary for population-level movement. In November of 2010, three bighorn overpasses, two measuring 50 feet (15 m) wide and one measuring 100 feet (30.5 m) by 202 feet (61.6 m) long were completed over US 93. These overpasses were built much in the spirit of the Utah overpass across I-15;

they are simple bridges over a four-lane highway. Within days of installing the monitoring cameras, Arizona Game and Fish biologists documented both male and female sheep moving over the overpass[2].

Based on the monitoring results from Arizona, anecdotal information from other locations, an understanding of sheep's predator avoidance strategies, and the apparent reluctance of ewes to use bridged underpasses, overpasses are the recommended structure type for passing multiple members of both sexes of a bighorn sheep population.

2.2.1-7. Arboreal Fauna

Species in this guild move primarily through the canopy rather than on the ground surface, such as flying squirrels, arboreal voles and some bats. The best mechanism for providing safe passages for species in this guild is to construct a canopy-level structure across the roadway, for example, a rope or metal bridge (Fig. 27). A second method that is still under investigation is the placement of tall poles alongside a two-lane road to assist gliders over the road and flow of traffic. In North Carolina, several pairs of these tall poles have been placed along two lane roads with trees on both sides of the road. There are platforms toward the top of these poles that are meant as "launching" pads for the flying squirrels in the area. Cameras mounted on these platforms have recorded successful flying squirrel passage between poles (A. Burroughs NCDOT, personal communication). Researchers in North Carolina are investigating this method further and will make the results public at some point in the future.

Figure 27. Arboreal Crossing, Europe © M. Huijser

[2] A video clip of two rams using the crossing can be viewed at: http://www.youtube.com/watch?v=vrKCM26r1FM.
A February 2011 article from Arizona Fish and Game on the crossings can be found at: http://azgfd.net/artman/publish/NewsMedia/First-bighorn-sheep-documented-on-overpasses.shtml.

2.2.1-8. Aerial Fauna

Aerial Fauna are animals that move primarily by flying, such as songbirds, raptors, bats, and flying insects, including butterflies. As animals in this group are capable of flying over a roadway, the primary concern with regards to connectivity across roads is to divert them from flying into the path of traffic. Several mitigation methods can help minimize collisions and also the effects of habitat fragmentation caused by road infrastructure.

Crossing structures can assist flying fauna to fly below or over the flow of roadway traffic. Large structures that cross high above natural areas allow flying creatures the ability to maintain flight underneath the road. Such structures include causeways, viaducts and expanded bridges. In Europe, vegetated overpasses have also been shown to provide safe crossings for woodland bird species (Jacobson 2005). In this study there were significantly more bird flights over vegetated overpasses compared to passes directly over the road, and in some cases the birds included the wildlife overpasses within their territories.

Directing animals to fly high above or away from the flow of traffic is another alternative. Where bridges cross over waterways or near aquatic areas, birds may use the airflow at the bridge to swoop in and gain lift. This behavior has been documented in areas along the coasts of Texas and Florida. The Departments of Transportation in these states have installed either aluminum fence poles (Texas) or poly vinyl chloride (pvc) pipes (Florida) on such bridges to create the appearance of a larger barrier thereby causing the birds to fly higher over the bridge as well as the traffic (Jacobson 2005).

Predatory birds such as owls are typically killed along roadways when they find a source of rodents within the right-of-way. In Idaho and Oregon along I-84, owl spring migrations occur at the same time farmers are plowing their fields, thus driving out local rodents toward the interstate right of way for cover and forage. While no solutions have been initiated as of yet, it appears the problem could be partially mitigated by keeping rodents out of the right of way, or by preventing owls from accessing the prey through the placement of low fences, or by placing materials that flap in the wind to discourage the owls from approaching the right of way. Another opportunity exists in areas where enough water is present to support the growth of bushes in the median, such as sage brush in this area of Idaho. This would make aerial attacks more difficult from a distance across the lanes of traffic.

In Arizona, the first recorded bird crossing was constructed in Tucson. The burrowing owls nesting along the road were in danger of flying over the road barriers and into traffic. A median area that acted as a planter was placed with fast growing trees and shrubs. This acted as a diversion device to alter the flight of the owls up and over traffic (Fig. 28). Unfortunately, habitat destruction nearby forced the relocation of these birds.

Figure 28. Rick Ellis, Pima County Planner in Arizona at an owl crossing, where trees were planted to divert flying owls over traffic flow © P. Cramer

These Species Movement Guilds are meant to better classify an animal of concern near a transportation corridor. Interested biologists may not know if a particular species has been studied for their response to mitigation. By placing that species within its respective Species Movement Guild, generalizations can be made as to which mitigation solutions may work for that species. The overview above represents the best compilation of the current state of the science of wildlife and transportation in the United States and Canada.

2.3. Structure Functional Classes

The term 'wildlife underpasses' connotes many different structures from the smallest culverts that may pass a salamander, to the space under a highway viaduct, tens to hundreds of feet above the landscape. This classification of transportation infrastructure into defined Structure Functional Classes, provides a definitive set of conditions for four different underpasses, the overpass, and two unusual designs for passages (Table 2). The critical dimensions for breaks among the four classes are based on heights and widths of structures, which are dictated by engineering design constraints and wildlife characteristics that define individual species' willingness to move through a structure. These classifications are supported with the information below. This classification of structure types can help transportation planners, biologists and engineers to relate wildlife passage needs to a specific structure type or types with a common vocabulary. This classification was first proposed in the National Academies research 'Evaluation of the Use and Effectiveness of Wildlife Crossings' (Bissonette and Cramer 2008) and the accompanying website (Bissonette and Cramer 2006) and has been subsequently updated and modified for this research.

TABLE 2: Structure Functional Classes, viewed from a species perspective. Generally, species that use small structures will use larger structures if appropriate cover and other features are provided, but most species cannot use smaller classes. This table is for terminology only and is not intended to be used for structure design. It can be used for generalized discussions early in planning process. It is not intended to be prescriptive since each site requires site-specific planning by qualified biologists and engineers. These structure classes were developed by the authors in collaboration with Sandra Jacobson, U.S.D.A. Forest Service.

Crossing Structure Category	Function	Approximate Dimension Range (Span x Rise)	Passage Examples	Species Examples	Behavioral Attributes	Species Movement Guilds (Potential)
Class 1: Small Underpass	Provides enclosed protection for small animals that require cover.	Metal pipe culverts or small box culverts 1.5 m (5') span or less	Small bridges, dry culverts, and ephemerally flooded drainage culverts. Continually flooded drainage structures have limited functionality for terrestrial species but may function for some aquatics.	Amphibians, reptiles, small mammals and some medium-sized mammals (badger, fox, bobcat). Aquatic species include fish, aquatic amphibians, and invertebrates.	Small animals that prefer cover or do not mind confinement.	Low Mobility Fauna, Mobile Small Fauna, Highly Mobile Adaptive Fauna
Class 2: Medium Underpass	Provides some cover yet more openness than Class 1 structures for animals smaller than deer. If water is conveyed, allows for stream simulation including unwetted natural banks.	Underpasses larger than 1.5 m (5') span, to 2.4 m (8') span x 2.4 m (8') rise	Box culverts, arch pipes and other culvert shapes, small bridges.	Coyote, bobcat, ocelot, lynx and some large carnivores (black bear, puma); alligator.	Medium sized mammals that require some cover and some openness to see through passage.	Low Mobility Fauna, Mobile Small Fauna, Highly Mobile Adaptive Fauna, Adaptive Ungulates
Class 3: Large Underpass	Provides an approximate minimum for ungulates, especially deer, and other species that require visibility, maneuverability, and moderated noise. May allow some natural processes including vegetation growth and stream processes.	Underpasses with minimum dimensions: 6.1 m (20') span x 2.4 m (8') rise, or 3.1 m (10') span x 3.1 m (10') rise, and open span bridges	Box culverts, large arch pipes, bridges including open span bridges. Multiple chambered structures are considered as individual units.	Ungulates use structures in approximate proportion to their size (ie, deer can use smaller structures than elk or moose) although pronghorn require larger structures (minimum 18.3 m span x 5.5 m rise). Large carnivores (wolf, grizzly bear, black bear, puma).	Larger mammals that require structures of a minimum size for passage.	Low Mobility Fauna, Mobile Small Fauna, Highly Mobile Adaptive Fauna, High Openness Mobile Fauna, Adaptive Ungulates

Crossing Structure Category	Function	Approximate Dimension Range (Span x Rise)	Passage Examples	Species Examples	Behavioral Attributes	Species Movement Guilds (Potential)
Class 4: Extensive Bridge (includes Viaducts)	Allows ecosystem processes to permeate highway such as wetland water flow, vegetation growth, and entire floodplains. Provides excellent horizontal visibility for animals requiring openness.	Bridge extending over several spans. Designed for each site so dimensions vary. May allow more sunlight under structure than other types.	Viaducts are long bridges elevated over the landscape in a series of smaller spans, often connecting points of equal height. Typically over wetlands, steep terrain.	Most species including wetland species, birds, pronghorn.	Viaducts are particularly good for wary species including carnivores that may not approach other structures, or low mobility species such as mollusks that require vegetation throughout the structure.	Low Mobility Fauna, Mobile Small Fauna, Highly Mobile Adaptive Fauna, High Openness Mobile Fauna, Adaptive Ungulates, Arboreal Fauna, Aerial Fauna
Class 5: Wildlife Overpass	Provides an open top and expansive visibility of the horizon for animals preferring unenclosed spaces. Allows full sunlight and precipitation for vegetation growth. May allow small, sunlit water features.	Overpass structure for wildlife to pass over roadway, as small as 6.7 m (22') wide, but preferably at least 50 m (164') wide.	Overpasses with soil and plant growth.	All ungulates (pronghorn not proven yet), carnivores (bear, puma, forest carnivores). Songbirds and insects including butterflies.	Any species that requires natural habitat, sunlight or ambient conditions for movement.	Low Mobility Fauna, Mobile Small Fauna, Highly Mobile Adaptive Fauna, High Openness Mobile Fauna, Adaptive Ungulates, Arboreal Fauna, Aerial Fauna
Class 6: Specialized Culvert	Allows outside environmental conditions to occur within the entire structure, including light, temperature and moisture.	Current designs are small culverts less than .5 m (24") span but could be larger structures.	Trench drains and slotted culverts.	Reptiles and amphibians	Reptiles and amphibians that require ambient outside conditions to survive and disperse, or to orientate during movements.	Low Mobility Fauna
Class 7: Canopy Bridge	Provides an arboreal passage for animals that typically do not descend below tree canopy to ground.	Adequate to cross all traffic lanes. May be connected to trees in the median.	Treetop rope bridges, or modified wire or metal structures.	Squirrels, arboreal rodents, opossum. Potential for insects and plants.	Species that move through the canopy rather than on the ground surface.	Arboreal Fauna

Figure 29. Example of a Class 1 Small Culvert, I-70 CO © J. Kintsch

Figure 30. Example of a Class 2 Medium Culvert, I-90 WA © J. Kintsch & P. Cramer

Class 1: Small Underpasses

Small passages made of metal or concrete pipes and culverts up to 5 feet (1.5 m) in diameter are typically (but not always) preferred by smaller mammals, amphibians and reptiles, and some medium sized animals such as badger, fox, and bobcat (Fig. 29). These species do not hesitate to enter confined spaces and may need cover and other conditions, such as moisture, that are more typically found in smaller spaces as opposed to larger, more open passages. Such conditions can be replicated in a larger passageway by maintaining woody or vegetative cover through the passage or by laying a small pipe through the larger culvert to accommodate small animal passage. Culverts that accommodate water typically fall into this category. Some species require the moisture present with water courses, such as amphibians. Other species need more dry conditions. It is recommended that even these smaller structures be designed or enhanced to allow some terrestrial movement by installing raised shelves along the sides of these aquatic passages.

Class 2: Medium Underpasses
Medium passages are underpasses that are larger than 5 feet (1.5 m) in span and up to 8 feet (2.4 m) in span, with an 8 feet (2.4 m) rise (Fig. 30). Height is used as the definitive measure at this level because the majority of existing passages in this size class are culverts where the height is equivalent or similar to the width or span. The definitive height of 8 feet (2.4 m) was used as the upper limit of the height of a crossing this size based on data gathered in the United States and Canada that included the dimensions of 128 existing wildlife crossings (Bissonette and Cramer 2008). Plotting the height of crossings by the number of crossings with that height, the data exhibited a break in groupings between the heights of 8 and 10 feet (2.4 and 3 m; Fig. 31). Eight feet (2.4 m) is also calculated as the upper size limit for medium-sized passages because the majority of mule deer determined to use underpasses in the previously mentioned studies used crossings greater than 8 feet high. By this definition, a 8'x8' standard box culvert (2.4x2.4 m) is the upper limit for

a medium underpass because deer typically do not prefer these passages, fully understanding that, in some instances, deer will use these smaller passages

Also included in this class are small bridges up to 8 feet (2.4 m) high. While still classified as medium underpasses, these bridges are much wider than a culvert of the same height and span, and provide a greater appearance of openness. Medium underpasses are typically used by medium sized animals such as coyotes, bobcat, lynx, black bear, and puma, and smaller low mobility and moderately mobile fauna such as snakes, turtles, marmots, otter, beaver, and some ground birds.

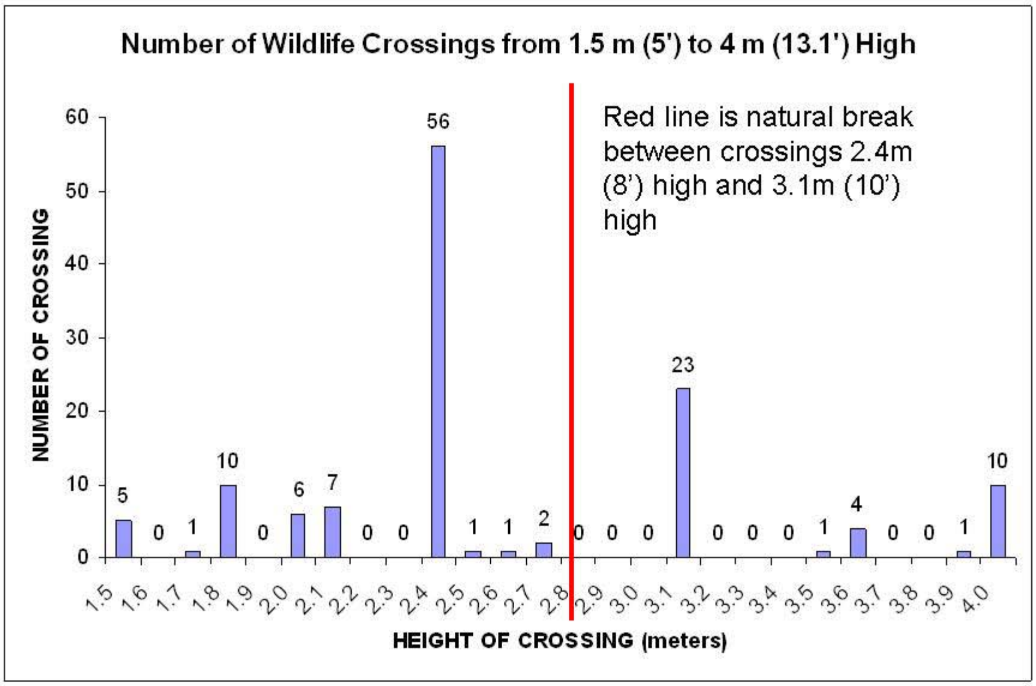


Figure 31. Height of 128 known wildlife crossings plotted versus the number of wildlife crossing structuress at that height. These wildlife crossing dimensions were taken from survey participants in the National Cooperative Highway Research Program study, 'Evaluation of the use and effectiveness of wildlife crossings' (Bissonette and Cramer 2008). All crossings included in this graph were specifically built for wildlife.

Class 3: Large Underpasses

The minimum dimensions for large underpasses are defined, in part, as passages that can regularly pass deer species (both mule and white-tailed). These passages are defined as having a minimum of a 10 feet (3 m) span by 10 feet (3 m) rise – typically culverts – up to a 20 feet (6.1 m) span by an 8 feet (2.4 m) rise. These values are a reflection of the typical size of prefabricated culverts such as 10 by 10

Figure 32. Example of a Class 3 Large Underpass arch culvert being used by mule deer under I-90 Washington © P. Cramer, J. Kintsch & WSDOT

Figure 33. Example of a Class 3 Large Underpass bridge structure being used by black tailed deer, SR 6, Washington © P. Cramer, J. Kintsch & WSDOT

feet (3x3 m) culverts, as well as larger arch culverts (Fig. 32). This class also includes all types of bridges, from those that are open span to those with multiple chambers where the individual units fall in this size range (Fig. 33). The smallest passage that has been monitored and verified used by deer is a 10 by 10 feet (3x3 m) culvert in Dowd Junction, Colorado (Reed et al. 1975). Donaldson (2005, 2006) documented limited use of a smaller culvert (10x6 ft [3x1.8 m]) by white-tailed deer in the eastern U.S., but recommends passage height be at least 12 feet (3.7 m). Gordon and Anderson (2003) recommend the minimum dimensions for a deer passage in their study area in Wyoming be at least 8 feet (2.4 m) high and 20 feet (6.1 m) wide. Based on these results and recommendations, the minimum size for a Large Underpass was determined to be either a 8'x20' (2.4x6.1 m) culvert; a 10'x10' (3x3 m) culvert; or a bridge at least 8 feet high and 32.8 feet wide (2.4x10 m). The latter is similar to the 8'x43' (2.4x13.1 m) bridges under Florida's I-75, which are used by white tailed deer (Foster and Humphrey 1995). Also included in this class are larger structures, such as span bridges, which are typically larger than these dimensions, with spans over 43 feet (13 m). The added width provides greater openness to a passage. These types of passages have been documented passing all kinds of species from Low Mobility Small Fauna, such as frogs, to Very High Openness Fauna, such as elk.

<u>Class 4: Extensive Bridges - Viaducts</u>
These passages are areas where the roadbed is elevated high above the landscape over great distances, such that wildlife and ecosystem process can function naturally in the landscape beneath the viaduct. These structures span hundreds of yards (meters) and are typically at least 15 feet (4.6 m) above the ground surface. Most species of wildlife can use these areas, including wetland and riparian species as well as flying animals (Fig. 34).

Figure 34. Example of a Class 4 extensive bridge or viaduct, I-70 Colorado © J. Kintsch

Figure 35. Example of a Class 5 Wildlife Overpass, NV © L. Bellis, Nevada DOT

Figure 36. Mule Deer on top of Nevada overpass © L. Bellis, Nevada DOT

Class 5: Wildlife Overpasses

Wildlife overpasses have been frequently used in Europe as an effective means for re-connecting habitats over roadways (Bank et al. 2002) and are increasingly being constructed in North America (Figs. 35 & 36). Currently there are only ten overpasses for wildlife in North America, ranging from a 22 feet (6.7 m) wide crossing built for mule deer in Utah; to a 50 feet (15.2 m) bighorn sheep overpasses in Arizona; to 164 feet (50 m) wide overpasses across the Trans-Canada Highway in Banff National Park. Ongoing studies of the two Banff overpasses offer some of the most comprehensive research to date on designing these types of structures. Monitoring has documented use by almost every large and meso-mammal species in the Park, from grizzly bear to elk to lynx (Clevenger and Waltho 2000, 2005; Clevenger et al. 2001). The open design and presence of natural vegetative cover literally extends habitat over the highway, facilitating its use by large carnivores and ungulates as well as small mammals, amphibians, and insects.

Two important design considerations that affect the effectiveness of a wildlife bridge are the width of the structure (Keller 1999; Pfister et al. 2002), and the presence of flat, clear lines of sight across the structure to habitat on the opposite side of the road (Clevenger et al. 2002). Pfister et al. (1997) observed that wildlife behavior was more natural on wider structures, and concluded that structures at least 197 feet (60 m) wide were more effective than those narrower than 164 feet (50 m). A parabolic design, where the structure ends are wider than the middle portion are believed to provide the most effective design for wildlife bridges (Clevenger et al. 2002). With this design, Clevenger et al. (2002) recommends that the narrowest portion of the structure should be approximately 230 feet (70 m) wide and extend out to 295 feet (90 m) at the ends to allow animals approaching from the side a better line of sight across the structure. A straight-line parabolic design is typically more cost-effective than a true hourglass design and provides the same benefits. In both Europe and North America, 164 feet (50 m) is regarded as the absolute minimum width for a multi-species overpass, and 197-230 feet (60-70 m) or more is a generally recommended, depending on other site-specific and engineering considerations (Keller 1999; Clevenger et al. 2002; Pfister et al. 2002). Current research projects in Utah, Arizona, Nevada, and Montana are finding that overpasses with much more narrow widths (less than or equal to 150 feet [45.7 m]) are passing individual species – including mule deer in Nevada and Utah; white-tailed deer in Montana; and bighorn sheep in Arizona – in numbers that are measured by the dozens to hundreds of passes per year. A more thorough review of overpasses in the western United States in the coming years is a necessary action to make better recommendations for the design of future overpasses.

Overpasses have also been built over above ground pipelines, with anecdotal evidence of caribou, moose, black bear and coyote use.

2.4. Monitoring Approach

2.4.1. Purpose and Methods

A field research component of this research was conducted in conjunction with the development of the Passage Assessment System (PAS). Little monitoring had been previously conducted to assess how wildlife in Washington use existing bridges and culverts; this field component was carried out to better inform the knowledgebase specific to the use of transportation infrastructure by wildlife in Washington. This component of the research project helped in refining the PAS and the accompanying Species Movement Guilds and Structural Functional Classes.

In April 2010 motion-triggered trail cameras were placed at six sites across Washington. These sites were selected to best represent different geographic areas, roads with variable number of lanes and different traffic volumes, and different types of structures. Due to funding limitations, sites greater than 200 miles from

Seattle were not selected. In June 2010, six additional cameras were placed at three additional sites. Three sites in the southwestern region of Washington were monitored: a box culvert at Mosquito Creek under US 101; a bridge over the Bone River on US 101; and a bridge over the Willapa River on SR 6. Three sites in central Washington were monitored: a corrugated steel wildlife crossing culvert under I-90 near North Bend; a double concrete box culvert under I-90 near Roslyn; and the Cle Elum River Bridge near Cle Elum. Two of the sites that had cameras placed during April, at North Bend, were pulled due to vandalism that resulted in the theft of two cameras. These sites were at the Snoqualmie trail bridges, and the South Fork Snoqualmie River bridges. They were not monitored longer than several days.

At each site, a camera was positioned at each end of the structure to best monitor all animal approaches and passes through the structures. The cameras were placed inside metal utility boxes and locked to bicycle cables which were embedded in 60 to 120 pounds of concrete on the inside bottom of the utility box. Cameras were checked every two weeks to change the batteries and retrieve photographic data. Data were entered into Excel spreadsheets for analysis. Monitoring activities continued until October 2010. The majority of these cameras are still in use by WSDOT at the writing of this report.

2.4.2. Overall Results

A complete summary of the monitoring results is presented in Appendix D 'Structure Evaluations, Monitoring Results and Recommendations'. The monitoring summaries provide an overview of the data, including the number of deer and elk at the site; whether the animals used the structure or were repelled; seasonal use of the structure by deer; and tallies of all species detected at the site. For each site, six sample pictures of the camera data are displayed to demonstrate wildlife activity at the site. Monitoring information can help WSDOT determine which species will use certain structures more readily than others. The summaries also help support and clarify conclusions drawn during the site evaluations and refine the recommendations provided to enhance the structures for wildlife passage.

Of particular note from the study results is the documented elk use of two large bridged structures under I-90, one at the South Fork Snoqualmie River near milepost 33, the other at the Cle Elum River near milepost 79. Research throughout the western United States has documented the species' reluctance to pass through confined spaces such as culverts or small, restricted bridges. However, photographic evidence compiled through this research project showed elk movements under bridges that were wide, but less than 10 feet (3 m) high. This new insight that elk may be willing to use low bridges so long as they are sufficiently wide helped inform the requirements quoted for elk in the Species Movement Guilds description (Chapter 2.2.1.1-6) and may help WSDOT and other agencies to better design cost-effective bridges suitable for elk.

A very interesting site included in this study was near North Bend, where a pair of corrugated steel culverts crosses under I-90 (milepost 29). These culverts are located in a thickly vegetated area. Judging from the characteristics of the structure itself and the fact the small stream through this crossing was placed underground for half of the crossing; it appears that these culverts were designed specifically for wildlife passage. If wildlife were not considered, the stream could have been shunted underground for the entire length of the passage. In the WSDOT Bridge Engineering Information System records this structure is listed as being built in 1976 and is listed as a game crossing. The structure is tied into an extensive segment of 8-feet (2.4 m) high wildlife fencing. This culvert appears to be among the most successful black bear crossings in the western U.S., as demonstrated by 31 black bear observations during 5 months of study. In comparison, study sites in two states combined (Montana and Utah) have tallied less than 12 successful black bear crossings over the course of two years. While the passage is very successful for black bear, only three bobcats approached and crossed through the structure, and seven of 19 approaches by coyotes were repelled. Our camera technician on several occasions could smell the bear presence in the culverts when she came to check the cameras. This may explain the low numbers of deer using it. It may also support the idea that in an area of high species diversity, multiple crossings may be necessary for prey, predator and even competitor species. A site visit in April 2011 by Dr. Cramer revealed multiple piles of elk fecal pellets on both sides of the highway at this site. This data further supports the idea that multiple species of prey and predators may be at this site, but only a select group (the predators) is predominately using the culvert.

Site visits in 2011 allowed for further examination of wildlife in the areas near the crossings. During site visits in April 2011, Dr. Cramer conducted vegetation and fecal pellet counts along transects that included 25 location points in a grid pattern on each side of the highway at sites where cameras were placed. Preliminary results of pellet counts revealed that the cameras that face the crossings are only capturing a portion of the animals located in the vicinity of the crossings. This was exemplified most strongly at the Mosquito Creek culvert (US 101, milepost 76.5), as well as the large corrugated steel culverts near North Bend (I-90, milepost 29). Only one elk was photographed at the west entrance to the Mosquito Creek culvert, yet there were dozens of piles of fresh elk pellets on that side of the highway in the vicinity of the culvert entrance. The monitoring transects for fecal pellets at the large culverts at North Bend also revealed dozens of elk fecal pellet piles on both sides of the highway. This added information lends further evidence to the theory that elk prefer not to use culverts. These site visits also revealed mule and black-tailed deer use of areas near the crossings. The data have not been analyzed sufficiently at this point to glean trends in the presence of deer and other species photographed in front of the cameras and the correlation to the fecal pellet groups found in these transects.

Deer in the study exhibited a willingness to pass through culverts smaller than the researchers predicted they would. Photographic data from the Mosquito Creek culvert under US 101, and the double box culvert under I-90 at Tucker Creek (milepost 73) showed a surprising amount of black-tailed deer using the US 101 culvert, and mule deer using the I-90 box culvert. These data had the researchers and WSDOT biologists re-thinking the culvert size limits that deer will navigate through. The Mosquito Creek culvert is only seven feet (2.1 m) high, just under 16 feet (14.9 m) wide in span, and 138 feet (42 m) long. The I-90 double box culverts at Tucker Creek are less than five feet (1.5 m) high, nine feet (2.7 m) in span, and 58 feet (17.7 m) long for each of the two culverts under opposing lanes of traffic. These culvert heights are typically considered too small for more than occasional mule deer passage. While the Mosquito Creek passage mainly passed females with young, and only passed one male, making it very limited as a passage for the deer population, the Tucker Creek culverts under I-90 passed females and young as well as 28 passages of male deer. The data from these cameras continues to inform our ideas of how deer will adapt to structures and suggest a need for additional research into the factors that affect passage use, such as traffic volumes, local adaptation, and habitat drivers, among others.

2.5. Passage Assessment System

The Passage Assessment System (PAS) guides practitioners through a series of targeted questions designed to characterize a bridge or culvert relative to its potential to functions as a wildlife passage. The PAS is one of several complementary tools to assist WSDOT in identifying important connectivity areas and design mitigation solutions to improve or restore permeability for native wildlife. While the Washington Wildlife Habitat Connectivity Analysis (WHCWG 2010) offers a broad-scale perspective of connectivity across the state, the PAS allows WSDOT biologists to assess permeability at the site scale, for example along targeted stretches of roadway identified as bisecting these landscape connections.

The PAS is intended as an evaluation tool to ensure that biologists ask the right questions in the field and fully document the conditions that may affect passage functionality for the diversity of target species. Upon completion, the biologists will have a complete passage assessment including preliminary ideas for improving the structure, which can be further refined during the project planning and design processes. The PAS provides an effective mechanism for determining which structures are suitable for enhancements to improve their functionality as wildlife passages or, if no such enhancements are appropriate, identify structure replacement needs for improved highway permeability for wildlife. In this way, the PAS can inform project plans and budgets at the earliest stages of the transportation planning and design process. Figure 37 depicts the major steps in identifying and evaluating existing structures for their potential to pass targeted wildlife species.

To begin the assessment process, it is necessary to first select the roadway segments of interests before conducting the PAS in the field. These may be areas that are

Major Steps in Identifying the Potential of Existing Structures for Wildlife Passage Based on Species Movement Guilds

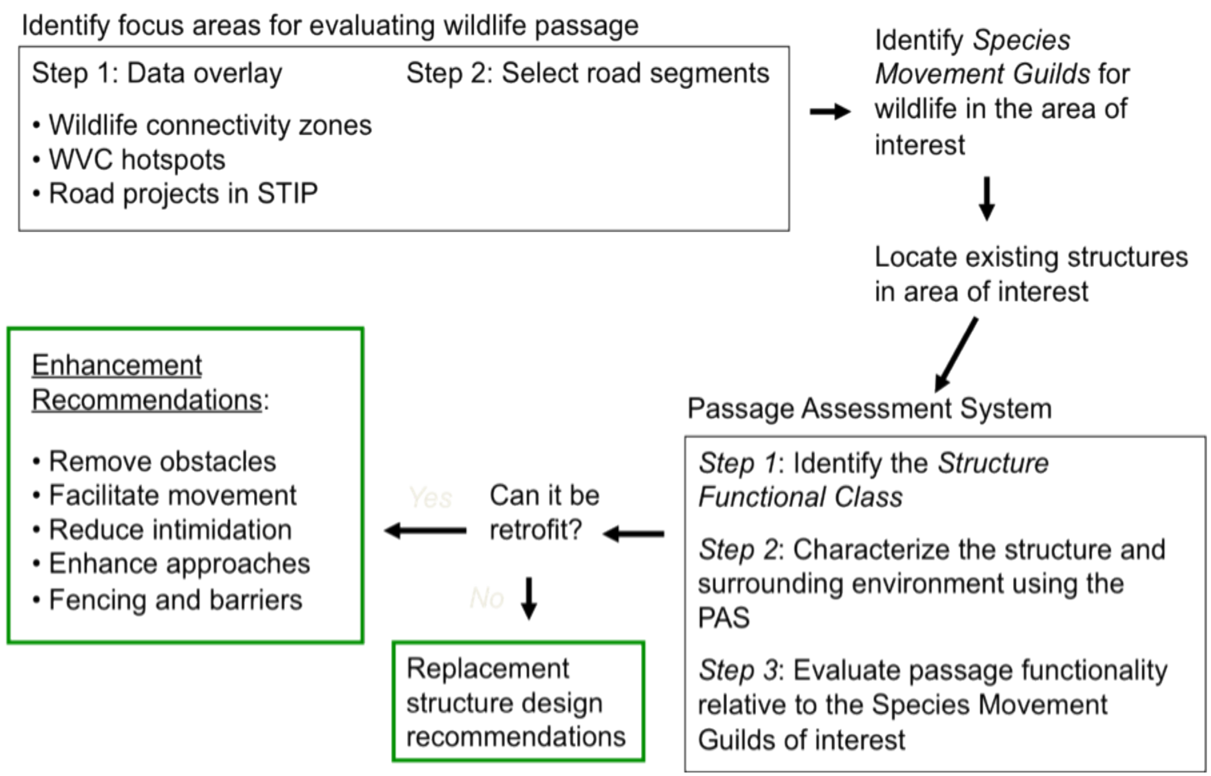


Figure 37. Flowchart identifying the major steps in evaluating the potential for an existing structure to pass native wildlife. In determining where to focus limited dollars, this process may be used at multiple locations along a given stretch of roadway to evaluate each potential safe passage opportunities (culverts, bridges and overpasses) and thereby identify which species guilds are well served by the existing conditions versus those that are underserved in the geographic area of interest.

identified connectivity zones; areas with high levels of animal-vehicle collisions, as determined from carcass removal data; areas that are slated for upcoming projects in short-term (3-5 year) planning or longer term (5-15 year) corridor planning; or, preferably, a combination of the above. A list of existing structures that fall in the roadway segments of interest can then be compiled from WSDOT's structures inventory. The locations identified on this list are where DOT biologists will use the PAS to evaluate existing structures for their functionality to pass target wildlife. Structures that are too old or are unsafe need not be evaluated, as they must be replaced; wildlife permeability considerations should then inform the design of the new structure. Other conditions that may affect whether a structure should be enhanced that are not considered in the PAS include land use and protected status of the lands on either side of a structure; the age or safety of a structure; or situations where an enhancement is not cost-effective relative to the replacement schedule.

The final step before taking the PAS into the field is to identify the species of interest whose habitat is bisected or adjacent to the roadway, and for which movement from one side of the road to the other may be of concern. In general, target species include those that are of danger in animal-vehicle collisions, such as deer, elk and moose; species of concern such as forest carnivores and threatened and endangered species; and other species that are sensitive to the barrier effect of roads. The Wildlife Habitat Linkages identified 16 focal species for the connectivity analysis. These species, if they occur in the geographic area of interest, should be included as target species. Appendix A identifies target species and associated Species Movement Guilds for each ecoregion in the state.

The assessment questions that compose the PAS were derived from a similar assessment system used in Colorado (Kintsch et al. 2011) and were further refined through a field test in Florida conducted by one of the researchers (Cramer). Following an additional series of refinements in collaboration with WSDOT, the researchers conducted a one-week field test, visiting 17 sites in southern and central Washington, including sites representing multiple bioregions and a range of structure types (pipe culverts, box culverts, arch culverts, small bridge underpasses and large bridge underpasses) as well as road types (from two to six lanes, including both divided and undivided highways). See Appendix D for complete site summaries. Final refinements to the PAS were made based on monitoring results and feedback an April 2011 workshop where the PAS was presented to WSDOT biologists from across the state.

The PAS is composed of three sections: General Questions, Undivided Highway, and Divided Highway, as well as a User's Guide provided for additional reference. For each structure that is being evaluated the user will complete 1) the General Assessment Questions, and 2) either the Divided or Undivided Highway Assessment Questions, depending on whether the structure of interest is located on a divided or undivided highway. Each of the questions in all three sections is fully clarified in the User's Guide. The complete PAS is available in hardcopy format in Appendix B of this report, or a digital copy is available from the Fish and Wildlife page of WSDOT's intranet. It is recommended that two biologists conduct the PAS together to capture a more comprehensive picture of a structure's passage characteristics.

The General Assessment Questions record basic information about the site, including a milepost, GPS point, a unique location code, the Species Movement Guilds present at that site (Chapter 2.2), the Structure Functional Class Type (Chapter 2.3), and whether the highway is divided or undivided. The answer to this last question – divided or undivided highway – will determine which form the user completes next, either the Divided or Undivided Highway Assessment Questions. While the questions posed are the same for a divided or undivided highway, they must be posed independently for each structure at a divided highway site.

At the start of the form the user is asked to respond to a set of preliminary questions. These are a collection of targeted questions designed to determine if there is a 'fatal flaw' with the structure relative to the Species Movement Guild(s) of interest. Each question should be considered relative to the Species Movement Guilds indicated. If a fatal flaw is identified, then the user need not complete the remaining PAS questions as the fatal flaw renders the structure unsuitable for enhancement; a newly designed and constructed structure is required to pass wildlife at that location. Fatal flaws may be specific to some or all guilds and include situations where a culvert is too long for the target species to pass through or where there is a lack of visibility from one end of a structure to the other.

If no fatal flaws are identified, the user then continues with the remaining questions, which are divided into distinct sections to guide the evaluation process. Some questions are repeated to capture conditions on both sides of a structure. The assessment questions include:

- Basic questions about the structure size and shape;
- Number of traffic lanes;
- Presence of parallel infrastructure, such as railroads, frontage roads or recreational paths;
- Questions about the inlet and outlet including specific inlet or outlet features (such as an apron or a perched outlet), the presence of obstructions (such as riprap or debris), vegetation cover, and the predominant land use within the immediate vicinity;
- Questions about the inside of the structure including visibility, water flow, presence of a dry pathway, substrate, noise, vegetative cover, skylights, obstructions, and the presence of a road or trail through the structure;
- Questions about fencing and walls associated with the structure including the type, height and condition of any fencing or walls, and presence of any escape mechanisms such as jump outs or one-way gates;
- Evidence of wildlife use;
- Evidence of human activity.

Throughout the PAS, users are encouraged to take a number of photos from multiple directions to fully capture a visual record of the structure and its attributes.

Finally, the user is instructed to document their general impressions regarding the functionality of the structure for each of the Species Movement Guilds of interest. For each guild, the user is instructed to rank the structure such that an A rank means that animals could pass through the structure as is or with small modifications; a C rank means that the structure could be functional with modest modification; and an F rank means that the structure cannot be enhanced to function as a wildlife passage. This section is a subjective assessment and responses should be based on the user's overall impression having completed the full PAS. Users are then asked which features could be changed to make the structure more functional for any Species Movement Guild of interest given an A or C rank. This question offers an opportunity for the user to suggest potential improvements. These may be amended and refined later, but this evaluation is helpful for capturing preliminary ideas and impressions while still in the field.

While users should answer all questions in the PAS, regardless of which Species Movement Guilds need passage at a given site, when determining whether or not a structure can be enhanced to improve functionality, if the only target species is a toad, for example, then the structure does not need to be evaluated for bears, and vice versa. However, at many sites there is a suite of species – and therefore, guilds – requiring safe passage.

Notably, the time of year at which the passage assessment is conducted can greatly alter perspectives on the functionality of that structure for a given Species Movement Guild, largely, because of differences in water flow through the seasons. In some areas, users may need to visit a site two or more times throughout the year to develop a more complete picture of how passage is affected by changing water levels. If the users can only visit a site once, the visit should ideally occur at a time when water levels are near their highest, and special consideration should be given to how either higher or lower water levels might affect passage through the structure. The length of time that high water flows may affect terrestrial passage should also be considered – if submersion occurs for less than a month or during a season when the target wildlife are not active, there may not be a conflict with wildlife passage. In addition, multiple visits throughout the year can also capture information about how vegetation growth may affect passage or visibility, as well as provide opportunities to detect signs of animal activity at different times of year.

Upon completing the PAS the user will be equipped to answer the question: 'can this structure be improved to accommodate passage for the target species present in this area?' It is possible, in some cases that a given structure may be enhanced to accommodate one or several of the target species, but cannot be suitably enhanced for all target species. The user is encouraged to consider the range of possible enhancements and how they could be implemented at each site being assessed. Chapter 2.5.2 provides guidance for identifying suitable enhancement options once it has been determined that a structure may be enhanced to improve permeability for the target species.

2.5.1. Refining the Passage Assessment System for Local Conditions

The PAS was developed and designed for Washington's DOT, however the assessment process is applicable regardless of geography. Once the species present in a given region have been classified according to the Species Movement Guilds, the PAS can be applied to that region. Some evaluation thresholds may need to be adjusted based on local conditions – such as a wildlife population that has adapted to human activity – or as new research becomes available, providing a more refined understanding of the factors affecting species' use of structures.

The PAS was developed for the purpose of assessing highway infrastructure located in non-urban environments. This evaluation system may also be applied to structures located in urban environments, however, users should be aware that urban wildlife are more adapted to human activity and infrastructure than their non-urban counterparts and may, therefore, have different tolerances for which the user will need to account when developing enhancement solutions.

2.5.2. Passage Enhancement Toolbox

Having determined that a structure *can* be enhanced for wildlife passage, biologists are then confronted with the question of *how* to enhance the structure to facilitate passage. Given the unique characteristics of every structure and the specific permeability objectives at each site, there is no simple answer to this question, however a number of commonly encountered situations are addressed in the Passage Enhancement Toolbox (Appendix C). The toolbox addresses a number of situations and provides examples of each. Enhancement options are organized into six categories:

- Remove obstacles to wildlife passage
- Facilitate movement and create pathways
- Reduce intimidation
- Enhance structure approaches
- Fencing and barriers
- Add or adjust structural features

Some enhancements require investments in maintenance, for example, removing sediment from a culvert or repairing holes in wildlife fencing; others require new investments, such as installing new fencing or guide walls, or constructing a new pathway through a structure. The toolbox is a living document that should be updated as revised as new techniques are tried and tested, providing an everexpanding array of enhancement options for DOTs to draw from. These enhancements can be further refined and customized to site-specific conditions during the DOTs project design processes, prior to implementation.

CHAPTER 3. CONCLUSIONS AND RECOMMENDATIONS

3.1. Conclusions

The PAS is an effective tool for evaluating the permeability of existing structures in WSDOT's transportation network. Using the PAS in conjunction with the Washington Wildlife Habitat Connectivity Analysis (WHCWG 2010) will allow biologists to conduct site-specific assessments within targeted high priority connectivity zones and in upcoming project areas as identified in the Statewide Transportation Improvement Program (STIP).

The PAS and all the supporting information that went into its development represents a first-time compilation of research results and theories on wildlife crossings across North America. The refinement of the Species Movement Guilds for this research allows any user of the information to categorize a species of interest to better understand how this species or similar species have been found move and behave with respect to roads and wildlife crossings. This allows for a fast, efficient classification of wildlife based on generalizations of movement behavior for broader categories of wildlife, regardless of known research on the specific species. The Structural Functional Classes, which were also refined for this research, can similarly be applied to all transportation culverts and bridges across North America. With the publication of this research in several different arenas, these classes are positioned to become the standard categorization for the science of transportation ecology. The development of the Passage Enhancement Toolbox is another resource that can be used by multiple users in North America and can be used as a reference for many different ways to mitigate and enhance existing structures along transportation corridors, regardless of locale. Overall, the information gathered in the development of the PAS – in addition to the PAS itself – will benefit the science and practice of transportation ecology as a whole.

The PAS was first introduced to group of WSDOT biologists in April 2011; additional experience using the PAS in the field will hone the biologists' skills in conducting and interpreting passage evaluations as a part of WSDOT's overall efforts to address permeability for wildlife and mitigate the impacts of the transportation network on connectivity for both terrestrial and aquatic wildlife. The PAS should be considered a living document as new research reveals how passage characteristics affect permeability for different types of species.

3.2. Next Steps and Recommendations

There are a number of ways in which the PAS may be enhanced over time to facilitate the assessment process and guide the design of appropriate mitigation enhancements. In addition to being available as hard copy data forms for use in the fields, the PAS is also ready to be programmed into handheld GPS-data collection units. Two such units are currently being beta-tested by the USDA Forest Service (contact: S. Jacobson). These and other units are scheduled to be tested in conjunction with a University of California at Davis and Caltrans research project in the summer of 2011. These units provide a streamlined mechanism for collecting and compiling field data. Both the hard copy forms and the programmable units may be easily updated and refined as needed. Continued use of the PAS by WSDOT, CALTRANS and other DOTs will help to inform any such updates.

Ongoing and new monitoring studies that help deepen our understanding of wildlife responses to crossing structures may also further inform and refine the PAS over time. With the deployment of field research cameras across Washington, WSDOT will be better equipped to record species' responses to transportation infrastructure and traffic. These data will greatly assist WSDOT in developing wildlife crossing structures and enhancements to existing structures that will promote permeability of roads for all wildlife. As the knowledgebase of what works and doesn't work for different species evolves, DOTs will be increasingly equipped to design effective crossing structures and improve the functionality of existing structures. Targeted monitoring where permeability enhancements have been implemented will create a positive feedback loop for maximizing the effectiveness of future improvements.

WSDOT is also advised to continue updating the Passage Enhancement Toolbox as new strategies are developed and tested in different situations. A complementary effort would be the compilation of engineering designs for each of these enhancement options so that WSDOT is equipped with a ready-to-go suite of designs from which engineers can draw upon when integrating permeability enhancements into transportation projects.

REFERENCES

Aresco, M. J. 2005. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69(2):549-560.

Aresco, M. J. 2011. The Lake Jackson Ecopassage. Website. http://www.lakejacksonturtles.org/

Arizona Fish and Game. 2011. First bighorn sheep documented on overpass. http://azgfd.net/artman/publish/NewsMedia/First-bighorn-sheep-documented-on-overpasses.shtml

Bank, F.G., C.L. Irwin, G.L. Evink, M.E. Gray, S. Hagood, J.R. Kinar, A. Levy, D. Paulson, B. Ruediger, and R.M. Sauvajot. 2002. Wildlife Habitat Connectivity Across European Highways. Federal Highway Administration. Alexandria, VA. http://international.fhwa.dot.gov/wildlife_web.htm

Barnum, S. 2003. Identifying the best locations to provide safe highway crossing opportunities for wildlife. Pages 246-252 in C.L Irwin, P. Garrett, and K. P. McDermott (eds). International Conference on Ecology and Transportation Proceedings. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. The Journal of Wildlife Management 59(2):228-237.

Bellis, M. A. 2008. Evaluating the effectiveness of wildlife crossing structures in southern Vermont. Unpublished thesis presented to the Graduate School of the University of Massachusetts Amherst, Amherst, MA. 115 pp.

Bissonette, J. A. and P. C. Cramer. 2006. Wildlife and Roads: A resource for mitigating the effects of roads on wildlife using wildlife crossings such as overpasses, underpasses, and crosswalks. http://www.wildlifeandroads.org/decisionguide/2_1_6.cfm

Bissonette, J. A. and P. C. Cramer 2008. Evaluation of the use and effectiveness of wildlife crossings. NCHRP Report 615. National Cooperative Highway Research Program, Transportation Research Board, National Academies, Washington, D.C. http://www.trb.org/Main/Public/Blurbs/160108.aspx

Brehm, K. 1989. The acceptance of 0.2 m tunnels by amphibians during their migration to the breeding site. Pages 29-42 in: T. E. S. Langton (Ed). Amphibians and Roads, Proceedings of the Toad Tunnel Conference. ACO Polymer Products, Shefford, England.

Bristo, K. and M. Crabb. 2008. Evaluation of distribution and trans-highway movement of desert bighorn sheep: Arizona Highway 68. Report prepared for Arizona Department of Transportation, Phoenix, AZ. 34 pp.

Cain, A. T., V. R. Tuovila, D. G. Hewitt, and M. E. Tewes. 2003. Effects of a highway and mitigation projects on bobcats in southern Texas. Biological Conservation 114:189-197.

Cavallaro, L., K. Sanden, J. Schellhase, and M. Tanaka. 2005. Designing road crossings for safe wildlife passage: Ventura County guidelines. Group Master's Project. Donald Bren School of Environmental Science and Management, University of California. Santa Barbara, CA. 49 pp.

Clevenger, A.P., B. Chruszcz, and K. Gunson. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal or Applied Ecology 38:1340-1349.

Clevenger, A. P., B. Chruszcz, K. Gunson, and J. Wierzchowski. 2002. Roads and wildlife in the Canadian Rocky Mountain Parks – movement, mortality, and mitigation. Final Report to Parks Canada. Banff, Alberta, Canada.

Clevenger, A. P. and M. P. Huijser. 2009. Handbook for Design and Evaluation of Wildlife Crossing Structures in North America. Department of Transportation, Federal Highway Administration, Washington D.C. http://www.westerntransportationinstitute.org/documents/reports/425259_Final_Report.pdf

Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.

Clevenger, A.P., and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology, 14(1):47-56.

Clevenger, A.P., and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation, 121:453-464.

Cramer, P. C. 2011. Determining wildlife use of wildlife crossing structures under different scenarios. Final Report to Utah Department of Transportation Research Division. July 2011 146pp. In Review.

Cramer, P. C., R. Hamlin, and K. Gunson. 2011. Montana US Highway 93 South wildlife crossing research. MDT 308445RP. 2010 Annual Progress Report. Prepared for Montana Department of Transportation. 26 pp. http://www.mdt.mt.gov/research/docs/research_proj/us93_wildlife/progress_jan11.pdf

Crooks, K., C. Haas, S. Baruch-Mordo, K. Middledorf, S. Magle, T. Shenk, K. Wilson and D. Theobald. 2008. Roads and connectivity in Colorado: animal-vehicle collisions, wildlife mitigation structures, and lynx-roadway interactions.

Report No. CDOT-2008-4. Colorado Department of Transportation, Denver, CO.

Dodd, C. K, W. J. Barichivich and L. L. Smith. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 141:35-46.

Dodd, N.L., J. W. Gagnon, S. Boe, K. Ogren and R.E. Scheinsburg. 2009. Effectiveness of wildlife underpasses in minimizing wildlife-vehicle collisions and promoting wildlife permeability across highways: Arizona Route 260. Report to Arizona Department of Transportation, Phoenix, AZ.

Dodd, N.L., J.W. Gagnon, A.L. Manzo, and R.E. Schweinsburg. 2007a. Video surveillance to asses highway underpass use by elk in Arizona. Journal of Wildlife Management (71):637-645.

Dodd, N. L., J. W. Gagnon, S. Boe, A. Manzo, and R. E. Schweinsburg. 2007b. Evaluation of measures to minimize wildlife-vehicle collisions and maintain permeability across highways: State Route 260, Arizona, USA. Final Project Report (2002-2006). Projects JPA 01-152 and JPA 04-024T. Arizona Transportation Research Center and the Federal Highway Administration, Phoenix, AZ.

Donaldson, B. M. 2005. Final Report: The use of highway underpasses by large mammals in Virginia and factors influencing their effectiveness. Virginia Transportation Research Council, Virginia Department of Transportation and the University of Virginia, VTRC 06-R2, Charlottesville, VI.

Donaldson, B. 2006. The use of highway underpasses by large mammals and other wildlife in Virginia and factors influencing their effectiveness. In Transportation Research Board 2006 Annual Meeting. CD ROM. Transportation Research Board, National Research Council, Washington, D.C.

Fitzgerald, J.P., C.A. Meaney, and D.M. Armstrong. 1994. Mammals of Colorado. University Press of Colorado. Niwot, CO.

Ford, S. G. 1980. Evaluation of highway deer kill mitigation on SIE/LAS-395. Report No. FHWA/CA/TP-80/01. U.S. Department of Transportation, Federal Highway Administration and California Department of Transportation, Sacramento, CA.

Foresman, K. R. 2004. The effects of highways on fragmentation of small mammal populations and modifications of crossing structures to mitigate such impacts. Final report to Montana Department of Transportaiton, Helena, MT. 39 pp.

Foster, M. L. and S. R. Humphrey. 1995. Use of wildlife underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.

Gagnon J. W. 2011. US 93 Bighorn Sheep Crossing. www.youtube.com/watch?v=vrKCM26r1FM.

Gloyne, C. C. and A. P. Clevenger. 2001. Cougar Puma concolor use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. Wildlife Biology 7:117-124.

Gordon, K. and S. Anderson. 2003. Evaluation of an underpass installed in U.S. Highway 30 at Nugget Canyon, Wyoming, for migrating mule deer. Report FHWA-WY-3/01. Wyoming Department of Transportation. Cheyenne, WY.

Gordon, K., J. Haschke, R. Plumb, and S. Anderson. 2003. Evaluation of ungulate use of I-80 underpasses. Final Report May 2003. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie.

Grilo, C., J. A. Bissonette, and P. C. Cramer. 2010. Mitigation measures to reduce impacts to biodiversity. In: (Editor S.R. Jones), Highways: Construction, Management, and Maintenance. Nova Science Publishers, Inc. Pages 74-114.

Haas, C.D. 2000. Distribution, relative abundance, and roadway underpass responses of carnivores throughout the Puente-Chino Hills. Master Thesis, California State Polytechnic University, Pomona, CA.

Huijser, M. P. and K. J. S. Paul. 2008. Wildlife-vehicle collision and crossing mitigation measures: a literature review for Parks Canada, Kootenay National Park. Report No. 4W1929 A. Parks Canada, Radium Hot Springs, British Columbia, Canada.

Jackson, S. D. 2003. Proposed design and considerations for use of amphibian and reptile tunnels in New England. University of Massachusetts, Amherst. http://umass.edu/nrec/onlinedocs.html

Jackson, S. D. 1996. Underpass systems for amphibians. In G. L. Evink, P. Garrett, D.Seigler, and J. Berry (eds). Trends in Addressing Transportation Related Wildlife Mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar. State of Florida Department of Transportation, Tallahassee, FL.

Jackson, S. D. and M. N. Marchand. 1998. Use of a prototype tunnel by painted turtles, Chrysemys picta. Unpublished Note. URL: www.umass.edu/nrec/onlinedocs.html

Jackson, S. D., and T. F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders Ambystoma maculatum under roads. Pages 93-99 in: T. E. S. Langton (Ed). Amphibians and Roads, Proceedings of the Toad Tunnel Conference. ACO Polymer Products, Shefford, England.

Jacobson, S. L. 2005. Mitigation measures for highway-caused impacts to birds. USDA Forest Service General Technical Reprint PSW-GTR-191. Pages 1043-1050.

Jacobson, S.L. and D.C. Jacobson. 2007. An alternative to the openness 'ratio' using underpass physical attributes and behavioral implications of deer vision and hearing capabilities. In: C.L. Irwin, D. Nelson, and K.P. McDermoot.

Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC. p. 605.

Jochimsen, D. M., C. R. Peterson, K. M. Andrews, and J. W. Gibbons. 2004. A literature review of the effects of roads on amphibians and reptiles and the measures used to minimize those effects. Report to the Idaho Fish and Game Department and the USDA Forest Service. Idaho State University and Savannah River Ecology Lab, University of Georgia.

Keller, V. 1999. The use of wildlife overpasses by mammals: results from infra-red video surveys in Switzerland, Germany, France and the Netherlands. Report to Infra Eco Network Europe (IENE), Fifth IENE meeting, 14-17 April 1999. Budapest, Hungary.

Klafki, R. 2002. East Kootenay badger project case study: adult female badger use of culverts under Highway 93 south of Cranbrook, British Columbia, Canada. Sylvan Consulting, LTD, Invermer, British Columbia.

Kintsch, J., P. Singer, M. Huijser, J. Crane, and A. Huyett. 2011. A regional ecosystem framework for terrestrial and aquatic wildlife along the I-70 Mountain Corridor, Colorado: an Eco-Logical field test. Report to the Colorado Department of Transportation, Denver, CO.

Leete, P. 2010. Best practices for meeting DNR General Public Waters Work Permit GP 2004-001. September 2010 Edition. Minnesota Department of Natural Resources. Minneapolis, MN. http://www.dnr.state.mn.us/waters/watermgmt_section/pwpermits/gp_2004_0001_manual.html

Little, S. J., R. G. Harcourt, and A. P. Clevenger. 2002. Do wildlife passages act as prey-traps? Biological Conservation. 107:135-145.

Lyren, L. M. 2000. Movement patterns of coyotes and bobcats relative to road underpasses in the Chino Hills are of Southern California. Master Thesis, California State Polytechnic University, Pomona, California.

Massachusetts Department of Transportation. 2010. Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams. Massachusetts Department of Transportation, Highway Division. Boston, MA. 117pp. http://www.mhd.state.ma.us/downloads/projDev/Design_Bridges_Culverts_Wildlife_Passage_122710.pdf

McCollister, M. F., and F. T. Van Manen. 2010. Effectiveness of wildlife underpasses and fencing to reduce wildlife-vehicle collisions. Journal of Wildlife Management 74:1722-1731.

McDonald, M. G. 1991. Glenn Highway moose monitoring study. Final Report to the Alaska Department of Transportation and Public Facilities, Anchorage, AK.

McDonald, W. and C. C. St. Clair. 2004. Elements that promote highway crossing structure use by small mammals in Banff National Park. Journal of Applied Ecology 41:82-93.

McKinney, T. and T. Smith. 2006. Distribution and trans-highway movements of desert bighorn sheep in northwestern Arizona. Final report to Arizona Department of Transportation and Federal Highway Administration. Phoenix, AZ.

Newhouse N.J. and T. A. Kinley. 2002. Annual update on population ecology of badgers in the East Kootenay: progress report. Columbian Basin Fish and Wildlife Compensation Program, Forest Renewal B.C., East Kootenay Environmental Society, and Parks Canada. British Columbia, Canada. 8 pp.

Ng, S. J., J. W. Dole, R. M. Sauvajot, S. P. D. Riley, and T. J. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation 115:499-507.

Pfister, H.P., V. Keller, H. Reck, and B. Georgii. 1997. Bio-okologische Wirksamkeit von Grunbrucken uber Verkehrswege [Bio-ecological effectiveness of wildlife overpasses or "green bridges" over roads and railway lines]. Herausgegeben vom Bundesministerium fur Verkehr Abeteilung Straβenbau. Bonn-Bad Godesberg, Germany.

Pfister, H.P., V. Keller, D. Heynen, and O. Holzgang. 2002. . Strasse und Verkehr, 3:101-108.

Puky, M. and Z. Vogel. 2004. Amphibian mitigation measures on Hungarian roads: design, efficiency, problems and possible improvement, need for coordinated European environmental education strategy. In: Proceedings of the IENE Conference on Habitat Fragmentation Due to Transportation Infrastructure. Infra Eco Network Europe, Brussels (13-15 Novemeber, 2003, Brussles).

Reed, D. F. 1981. Mule deer behavior at a highway underpass exit. Journal of Wildlife Management 45(2):542- 543.

Reed, D. F., T. D. I. Beck, and T. N. Woodward. 1979. Regional deer-vehicle accident research. Report No. FHWA-RD-79-11. U.S. Department of Transportation, Federal Highway Administration, Washington, D.C.

Reed, D. F, T. N. Woodard, and T. M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. Journal of Wildlife Management 39:361-367.

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

Sawyer, H. and C. LeBeau. 2011. Evaluating mule deer crossing structures in Nugget Canyon: 2010 progress report. Report to Wyoming Department of Transportation, Cheyenne WY. 21 pp.

Sawyer, H., and B. Rudd. 2005. Pronghorn roadway crossings: a review of available information and potential options. Report to Federal Highway Administration, Wyoming Department of Transportation, and Wyoming Game and Fish Department, Cheyenne, WY.

Singer F. and J. Doherty. 1985. Managing mountain goats at a highway crossing. Wildlife Society Bulletin 13:469-477.

Singer, P., A. Huyett, J. Kintsch and M. Huijser. 2011. Interstate 70 Eco-Logical Monitoring Report. Report to the Colorado Department of Transportation, Denver, CO.

Sweanor, L. L., K. A. Logan, and M. G. Hornocker. 2000. Cougar dispersal patterns, metapopulation dynamics, and conservation. Conservation Biology 14(3):798-808.

United States Geological Survey. 2011. Paynes Prairie Ecopassage Project. USGS Southeast Ecological Science Center, Gainesville, FL. http://fl.biology.usgs.gov/Amphibians_and_Reptiles/Paynes_Prairie_Project/paynes_prairie_project.html

Washington Department of Fish and Wildlife. 2000. Fish passage barrier and surface water diversion screening assessment and prioritization manual. Salmonid Screening, Habitat Enhancement, and Restoration Section, Washington Department of Fish and Wildlife, Olympia, WA. 81pp.

Washington Wildlife Habitat Connectivity Working Group (WHCWG). 2010. Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation, Olympia, WA. http://www.waconnected.org/statewide-connectivity.php

West, P.W. 2007. Wildlife Connectivity Across Utah's Highways – Updated. Report No. UT-06.09, Utah Department of Transportation. Salt Lake City, UT. 55pp.

Woltz, H.W., J.P. Gibbs and P.K. Ducey. 2008. Road crossing structures for amphibians and reptiles: informing design through behavioral analysis. Biological Conservation 141:274 -2750.

APPENDICES

Appendix A. Focal Species and Species Movement Guilds for the State of Washington

Appendix B. Passage Assessment System (PAS)

Appendix C. Passage Enhancement Toolbox

Appendix D. Structure Evaluations, Monitoring Results, and Recommendations for Improving Permeability for Terrestrial Wildlife in Washington State

APPENDIX A. FOCAL SPECIES AND SPECIES MOVEMENT GUILDS FOR THE STATE OF WASHINGTON

			Bioregion				
Species Guild	**Common Name**	**Scientific Name**	**Semi-Desert Matrix**	**N. Rocky Mt Forest Matrix**	**Subalpine**	**Alpine**	**Vancouverian**
Low Mobility Small Fauna	Cascades Frog	*Rana cascadae*			X		
	Columbia Spotted Frog	*Rana luteiventris*		X	X		
	Creeping Vole	*Microtus oregoni*					X
	Gopher Snake	*Pituophis catenifer*	X	X			
	Least Chipmunk	*Tamias minimus*	X				
	Northern Red-legged Frog	*Rana aurora*					X
	Northwestern Garter Snake	*Thamnophis ordinoides*					X
	Northern Alligator Lizard	*Gerrhonotus coerulea*					X
	Pika	*Ochotona princeps*				X	
	Sagebrush Lizard	*Sceloporus graciosus*	X				
	Southern Alligator Lizard	*Gerrhonotus multicarinatus*		X			
	Tiger Salamander	*Ambystoma tigrinum*	X				
	Vagrant Shrew	*Sorex vagrans*	X	X			X
	Western Rattlesnake	*Crotalus viridis*	X	X			
	Western Toad	*Bufo boreas*			X	X	XX
	Western Yellow-bellied Racer	*Coluber constrictor*	X	X			
	Yellow Pine Chipmunk			X			
Moderate Mobility Small Fauna	American Badger	*Taxidea taxus*	X				
	American Marten	*Martes americana*		X	X		X
	Black-tailed Jackrabbit	*Lepus californicus*	X				
	Fisher	*Martes pennanti*		X	X		X
	Mink	*Mustela vison*					X
	Olympic Marmot	*Marmota olympus*			X	X	
	Snowshoe Hare	*Lepus americanus*		X			X
	Spotted Skunk	*Spilogale putorius*					X
	Washington Ground Squirrel	*Spermophilus washingtoni*	X				
	White-tailed Jackrabbit	*Lepus townsendii*	X				
	Western Gray Squirrel	*Sciurus griseus*					X
	Yellow-Bellied Marmot	*Marmota flaviventris*	X				

Species Guild	Common Name	Scientific Name	Bioregion				
			Semi-Desert Matrix	N. Rocky Mt Forest Matrix	Subalpine	Alpine	Vancouverian
Adaptive High Mobility Fauna	Black Bear	*Ursus americanus*		X	X	X	X
	Bobcat	*Lynx rufus*	X				
	Canada Lynx	*Lynx canadensis*			X		
	Coyote	*Canis latrans*		X	X		X
High Openness High Mobility Carnivores	Mountain Lion	*Felis concolor*			X		X
	Gray Wolf	*Canis lupus*		X	X		
	Grizzly Bear	*Ursus arctos*		X	X	X	X
	Wolverine	*Gulo gulo*			X	X	
Adaptive Ungulates	Black-tailed Deer	*Odocoileus hemionus columbianus*					
	Moose	*Alces alces*		X	X		
	Mountain Goat	*Oreamnos americanus*		X	X	XX	X
	Mule Deer	*Odocoileus hemionus*	XX	XX	X	X	
	White-tailed Deer	*Odocoileus virginianus*					
Very High Openness Fauna	Bighorn Sheep	*Ovis canadensis*		X			
	Elk	*Cervus elaphus*		X	X	X	X
	Greater Sage Grouse	*Centrocercus urophasianus*	X				
	Pronghorn	*Antilocapra americana*					
	Sharp-tailed Grouse	*Tympanuchus phasianellus*	Y				
	White-tailed Ptarmigan	*Lagopus leucurus*			X	X	
	Woodland Caribou	*Rangifer tarandus*			X	X (limited)	
Arboreal Fauna	Northern Flying Squirrel	*Glaucomys sabrinus*		X			X
Aerial Fauna	Fringed Myotis	*Myotis thysanodes*					X
	Long-legged Myotis	*Myotis volans*					Y
	Northern Spotted Owl	*Strix occidentalis*		X			X
	Short-eared Owl	*Asio flammeus*	Y (limited)				
	Silver-haired Bat	*Lasionycteris noctivagans*				X	
	Townsend's Big-eared Bat	*Plecotus townsendii*				X	

PASSAGE ASSESSMENT SYSTEM: GENERAL QUESTIONS

Please complete this form for each structure visited

Date:

Location ID:

Location Code:

Route #:

Milepost:

GPS ID:

GPS Latitude:

GPS Longitude:

Structure Functional Class:	Class 1: small underpass		Class 2: medium underpass		Class 3: large underpass
	Class 4: extensive bridge		Class 5: wildlife overpass		Class 6: specialized culvert
	Class 7: canopy bridge				
Species Movement Guild (select all that apply):	Low Mobility Small Fauna	Moderate Mobility Small Fauna	Adaptive High Mobility Fauna	High Openness High Mobility Fauna	Adaptive Ungulates
	Very High Openness Fauna	Arboreal Fauna	Aerial Fauna		

Briefly describe the general environmental conditions at the time of the assessment (e.g., water levels, vegetation):

Bridge Number:				
Divided or Undivided:	Divided	Undivided		
Highway Direction:	East/West	North/South		
Roadway Photos Numbers:	1:	2:	3:	4:

PASSAGE ASSESSMENT SYSTEM: DIVIDED HIGHWAY

Special Note About Divided Highways with One Long Structure: This form is designed for divided highways with two separate structures cross under or over opposing traffic lanes, although it may also be use where one long structure crossing the entire roadway, including the median. In this case, users need not complete the sections of the Assessment that correspond to the median side inlet/outlet, which are not present when there is just one long culvert. Users should complete the Median section of the assessment regardless.

Preliminary Questions (i.e., fatal flaws)

Assess each of the following questions relative to the species guild of interest to determine whether the structure is fatally flawed for members of the Species Movement Guilds indicated:

Is the structure longer than 300 feet? Consider each structure under a divided highway separately. (fatal flaw for *Adaptive Ungulates* and *Very High Openness Fauna*)	No (continue)	Yes (structure is not suitable for enhancement)
Is the culvert slope > 30 degrees and 100' or longer? (fatal flaw for *all* Species Movement Guilds)	No (continue)	Yes (structure is not suitable for enhancement)
Is there extensive development/pavement in the immediate vicinity of one or both sides of the structure? (fatal flaw for *all* Species Movement Guilds)	No (continue)	Yes (structure is not suitable for enhancement)
Can you see through the structure to the other (for divided highways, consider each structure individually)? (if no, fatal flaw for *Adaptive Ungulates*, *Very High Openness Fauna* and *High Openness High Mobility Carnivores*)	Yes (continue)	No (structure is not suitable for enhancement)

West/North Structure

What is the shape of the structure? Round Pipe Squash Pipe Box Culvert Arch Culvert
Bridge Underpass - sloped Bridge Underpass - straight Bridge Overpass Other (text)

What is the structure material? Concrete Metal Plastic/Fiberglass Other (text)

[If Shape = Box] Are there multiple chambers? No Yes - Describe:

**If Yes, select the most appropriate chamber for terrestrial passage to answer the following questions.

[If Shape = Bridge Underpass] Is this a single span or multispan structure? Single span Multispan (1 or more supports)

**If Multispan, select the most appropriate chamber for terrestrial passage to answer the following questions.

[If Shape = Bridge Underpass] What is the material of the abutments on the West/North side?

Concrete Concrete/Soil Soil Riprap Gabian Wall Other (txt)

-What is the slope ratio? (horizontal:vertical) 0:1 1:1 2:1

[If Shape = Bridge Underpass] What is the material of the abutments on the East/South side?

Concrete Concrete/Soil Soil Riprap Gabian Wall Other (txt)

-What is the slope ratio? (horizontal:vertical) 0:1 1:1 2:1

Road Attributes

Number of lanes of road: ___________

Is there parallel infrastructure such as railroads, recreational paths, frontage roads, etc? No Yes - Describe:

Notes:

INLET SIDE (West/North Structure)

Photo Number	1:	2:	3:	4:	
Is there an apron at the inlet?	No	Yes, metal	Yes, concrete		
Does the culvert have wing walls?	No	Yes			

Structure Approximate Dimensions (functional dimensions if partiall

Are the distances measured for the whole structure or for a single chamber of a multispan structure? Whole Structure Single Chamber

For each measurement, indicate 'actual' or 'estimated' measurement with an 'x' in the appropriate column. Actual Estimated

-Height/Rise (feet) – can be marked as graduated ____________

-Width/Span (feet) – distance from side to side for animal crossing over/under road ____________

-Length (feet) – distance through the structure for animal crossing over/under road ____________

Obstructions

Is the immediate entrance blocked? None | Cattle Fence | Boulders humans would have to climb over | Rocks/Riprap (> volleyball size) | Rocks/Riprap (> baseball size) | Some rocks, not continuous | Thick Vegetation | Gate | Other:

Are there structures that block the entrance within 25 feet? No | Cattle Fence | Small Mesh Fence | Boulder Field | Stream Flow | High/Steep Cut or Fill Slope

Fill Slope

Is the structure located in a fill slope? No | Yes, < 20' high | Yes, > 20' high

-If yes, how is the structure situated in the slope? At the base | Midway on fill slope | Near top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the inlet? No | Yes, partially | Yes, completely

-If yes, select predominant type: Grasses | Bushes | Bushes/Trees

Is there vegetation/cover within 25-50' of the inlet? No | Yes, partially | Yes, completely

-If yes, select predominant type: Grasses | Bushes | Bushes/Trees

Land Use Within 100 feet of inlet:

Predominant land use: Forest | Prairie/Grassland | Agriculture | Wetlands | Shrub/Steppe | Mixed: Human/Natural | Residential | Commercial | Other:

Noise

What does passing traffic sound like at the entrance to the structure?

Silent | Low Rumble | Loud and Jarring

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?

0' | 0-6' | 6-30' | Undetermined

Is there a guard rail or jersey wall above the structure? No | Yes, structure only | Yes, extensive

Notes:

INSIDE STRUCTURE (West/North Structure)

Photo Number 1: 2: 3: 4:

Visibility

Does the inside of the structure appear much darker than the outside lighting? High Contrast Low Contrast

Is there a clear line of sight from one end of the structure(s) to the other? No Obscured Yes, complete visibility

Water Features

Is there perennial water flow through structure? No < 3' deep 3-10' deep >10' deep

Does there appear to be a dry natural substrate/dirt pathway through the structure during average flows?
None Dry Dirt Pathway Rock/Dirt Pathway Dry Rocky Pathway

Is there evidence that the dry pathway may be obliterated seasonally or during high water events?
No Yes Uncertain

Substrate

What is the substrate of the floor at the bottom/center of the structure? Concrete/Asphalt Metal
Plastic Rocks Dry Soil Stream Bottom Other (txt)

-Is there a natural bottom through the length of the structure? Yes No

-Is there a natural bottom across the width of the structure? Yes No, > 6" No, 6" or greater

Pathway Floor Substrate

Does the substrate through the structure appear similar to substrate outside of the structure? Yes No

-If No, what is the floor substrate?
Concrete Concrete with Steel Riprap (> baseball) Riprap (> volleyball) Boulders Other (text)

-If Yes, what is the minimum width of the dry natural pathway all the way through the structure?
<2 feet 2-5 feet 5-10 feet 10-20 feet 20-50 feet Over 50 feet

Vegetation

Is there vegetative cover and/or woody debris through the structure? None Some Logs, Down Trees
Some Grass/Brush Grasses Brush/Bushes/Trees

Noise

What does passing traffic sound like from the middle of the structure?
Silent Low Rumble Loud and Jarring

Other

Is there a road or trail through the structure? None Paved Road Dirt Road Railroad Paved Trail Dirt Trail

Are there obstructions inside the structure? None Debris Soil Baffles Gaps/Trenche Man-made Items

Is there a sky light in structure? No Yes

Notes:

OUTLET SIDE (West/North Structure)

Photo Number	1:	2:	3:	4:	
Is there an apron at the outlet?	No		Yes, metal	Yes, concrete	
Is the outlet perched?	No		Yes, < 0.5 feet	Yes, > 0.5 feet	
Does the culvert have wing walls?	No		Yes		

Structure Approximate Dimensions (functional dimensions if partiall

Are the distances measured for the whole structure or for a single chamber of a multispan structure? Whole Structure Single Chamber

For each measurement, indicate 'actual' or 'estimated' measurement with an 'x' in the appropriate column. Actual Estimated

-Height/Rise (feet) – can be marked as graduated ____________

-Width/Span (feet) – across or span of bridge/culvert along road ____________

-Length (feet) – for animal crossing over/under road ____________

Obstructions

Is the immediate entrance blocked? None | Cattle Fence | Boulders humans would have to climb over | Rocks/Riprap (> volleyball size) | Rocks/Riprap (> baseball size) | Some rocks, not continuous | Thick Vegetation | Gate | Other:

Are there structures that block the entrance within 25 feet? No | Cattle Fence | Small Mesh Fence | Boulder Field | Stream Flow | High/Steep Cut or Fill Slope

Fill Slope

Is the structure located in a fill slope? No | Yes, < 20' high | Yes, > 20' high

-If yes, how is the structure situated in the slope? At the base | Midway on fill slope | Near top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the outlet? No | Yes, partially | Yes, completely

-If yes, select predominant type: Grasses | Bushes | Bushes/Trees

Is there vegetation/cover within 25-50' of the outlet? No | Yes, partially | Yes, completely

-If yes, select predominant type: Grasses | Bushes | Bushes/Trees

Land Use Within 100 feet of outlet:

Predominant land use: Forest | Prairie/Grassland | Agriculture | Wetlands | Shrub/Steppe | Mixed: Human/Natural | Residential | Commercial | Other:

Noise

What does passing traffic sound like at the entrance to the structure?

Silent | Low Rumble | Loud and Jarring

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?

0' | 0-6' | 6-30' | Undetermined

Is there a guard rail or jersey wall above the structure? No | Yes, structure only | Yes, extensive

Notes:

Fencing/Walls (West/North Structure)

Photo Number 1: 2: 3: 4:

Is there fencing present on the West/North side of the structure? Yes No

Select type of fencing to *right* when facing structure: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-If curb or wall, does it have a lip? Yes No

-What is the height of fencing/wall? None ≤ 6" > 6" to ≤2' 2' to 4' 4 to 6' 6 to 8' >8'

-What is the mesh size? None 6x6" 6x6", graduating smaller to 2x3 at base Other:

-Is it connected to the structure? Yes No - small gap (≤0.5') No - large gap (>0.5')

-Does the fencing reach all the way to ground level without gaps? Yes No

-Is the fencing entrenched in the ground to prevent animals from digging under it? Yes No

- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure? Yes No

If no, what is the ROW fencing type: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-Minimum distance fence extends from structure:

≤ 10 feet 10-50 feet 50-100 feet >100 feet ~½ mile 1 mile Miles End not visible/known

Select type of fencing to *left* when facing structure: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-If curb or wall, does it have a lip? Yes No

-What is the height of fencing/wall? None ≤ 6" > 6" to ≤2' 2' to 4' 4 to 6' 6 to 8' >8'

-What is the mesh size? None 6x6" 6x6", graduating smaller to 2x3 at base Other:

-Is it connected to the structure? Yes No - small gap (≤0.5') No - large gap (>0.5')

-Does the fencing reach all the way to ground level without gaps? Yes No

-Is the fencing entrenched in the ground to prevent animals from digging under it? Yes No

- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure? Yes No

If no, what is the ROW fencing type: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-Minimum distance fence extends from structure:

≤ 10 feet 101 feet 120-250 feet ¼ mile ½ mile 2 mile Miles End not visible/known

What is the general condition of the fencing? Gaps and areas where fence is down Some tacking up of fence needed

Vegetation needs to be cleared from fence Fence in good working order

Is there an escape ramp(s) within a 1/2 mile of the structure in either direction? No Yes - 1 Yes - 2 or more

Is there a one-way gate(s) within a 1/2 mile of the structure in either direction? No Yes - 2 Yes - 2 or more

Are there uncontrolled driveways or intersections that cause breaks in the fencing within a 1/2 mile of the structure in either direction?

None 1 2-5 6-10 >10

Notes:

East/South Structure

What is the shape of the structure? Round Pipe | Squash Pipe | Box Culvert | Arch Culvert | Bridge Underpass - sloped | Bridge Underpass - straight | Bridge Overpass | Other (text)

What is the structure material? Concrete | Metal | Plastic/Fiberg | Other (text)

[If Shape = Box] Are there multiple chambers? No | Yes - Describe:

**If Yes, user will be prompted "Select the most appropriate chamber for terrestrial passage to answer the following questions"

[If Shape = Bridge Underpass] Is this a single span or multispan structure? Single span | Multispan (1 or more supports)

**If Multispan, user will be prompted "Select the most appropriate chamber for terrestrial passage to answer the following questions"

[If Shape = Bridge Underpass] What is the material of the abutments on the West/North side?

Concrete | Concrete/Soil | Soil | Riprap | Gabian Wall | Other (txt)

-What is the slope ratio? (horizontal:vertical) 0:1 | 1:1 | 2:1

[If Shape = Bridge Underpass] What is the material of the abutments on the East/South side?

Concrete | Concrete/Soil | Soil | Riprap | Gabian Wall | Other (txt)

-What is the slope ratio? (horizontal:vertical) 0:1 | 1:1 | 2:1

Road Attributes

Number of lanes of road: ____________

Is there parallel infrastructure such as railroads, recreational paths, frontage roads, etc? No | Yes - Describe:

Notes:

INLET SIDE (East/South Structure)

Photo Number	1:	2:		3:	4:
Is there an apron at the inlet?	No		Yes, metal	Yes, concrete	
Does the culvert have wing walls?	No		Yes		

***Structure Approximate Dimensions* (functional dimensions if partial)**

Are the distances measured for the whole structure or for a single chamber of a multispan structure? Whole Structure Single Chamber

For each measurement, indicate 'actual' or 'estimated' measurement with an 'x' in the appropriate column. Actual Estimated

-Height/Rise (feet) – can be marked as graduated	____________		
-Width/Span (feet) – across or span of bridge/culvert along road	____________		
-Length (feet) – for animal crossing over/under road	____________		

Obstructions

Is the immediate entrance blocked? None | Cattle Fence | Boulders humans would have to climb over | Rocks/Riprap (> volleyball size) | Rocks/Riprap (> baseball size) | Some rocks, not continuous | Thick Vegetation | Gate | Other:

Are there structures that block the entrance within 25 feet? No | Cattle Fence | Small Mesh Fence | Boulder Field | Stream Flow | High/Steep Cut or Fill Slope

Fill Slope

Is the structure located in a fill slope?	No	Yes, < 20' high	Yes, > 20' high
-If yes, how is the structure situated in the slope?	At the base	Midway on fill slope	Near top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the inlet?	No	Yes, partially	Yes, completely
-If yes, select predominant type:	Grasses	Bushes	Bushes/Trees
Is there vegetation/cover within 25-50' of the inlet?	No	Yes, partially	Yes, completely
-If yes, select predominant type:	Grasses	Bushes	Bushes/Trees

Land Use Within 100 feet of inlet:

Predominant land use:	Forest	Prairie/Grassland	Agriculture	Wetlands
Shrub/Steppe	Mixed: Human/Natural	Residential	Commercial	Other:

Noise

What does passing traffic sound like at the entrance to the structure?

Silent | Low Rumble | Loud and Jarring

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?

0' | 0-6' | 6-30' | Undetermined

Is there a guard rail or jersey wall above the structure? No | Yes, structure only | Yes, extensive

Notes:

INSIDE STRUCTURE (East/South Structure)

Photo Number 1: 2: 3: 4:

Visibility

Does the inside of the structure appear much darker than the outside lighting? High Contrast | Low Contrast

Is there a clear line of sight from one end of the structure(s) to the other? No | Obscured | Yes, complete visibility

Water Features

Is there perennial water flow through structure? No | < 3' deep | 3-10' deep | >10' deep

Does there appear to be a dry natural substrate/dirt pathway through the structure during average flows?
None | Dry Dirt Pathway | Rock/Dirt Pathway | Dry Rocky Pathway

Is there evidence that the dry pathway may be obliterated seasonally or during high water events?
No | Yes | Uncertain

Substrate

What is the substrate of the floor at the bottom/center of the structure? Concrete/Asphalt | Metal
Plastic | Rocks | Dry Soil | Stream Bottom | Other (txt)

- -Is there a natural bottom through the length of the structure? Yes | No
- -Is there a natural bottom across the width of the structure? Yes | No, > 6" | No, 6" or greater

Pathway Floor Substrate

Does the substrate through the structure appear similar to substrate outside of the structure? Yes | No

- -If No, what is the floor substrate?
  Concrete | Concrete with Steel | Riprap (> baseball) | Riprap (> volleyball) | Boulders | Other (text)
- -If Yes, what is the minimum width of the dry natural pathway all the way through the structure?
  <2 feet | 2-5 feet | 5-10 feet | 10-20 feet | 20-50 feet | Over 50 feet

Vegetation

Is there vegetative cover and/or woody debris through the structure? None | Some Logs, Down Trees
Some Grass/Brush | Grasses | Brush/Bushes/Trees

Noise

What does passing traffic sound like from the middle of the structure?
Silent | Low Rumble | Loud and Jarring

Other

Is there a road or trail through the structure? None | Paved Road | Dirt Road | Railroad | Paved Trail | Dirt Trail

Are there obstructions inside the structure? None | Debris | Soil | Baffles | Gaps/Trenche | Man-made Items

Is there a sky light in structure? No | Yes

Notes:

OUTLET SIDE (East/South Structure)

Photo Number	1:	2:	3:	4:	
Is there an apron at the outlet?	No	Yes, metal	Yes, concrete		
Is the outlet perched?	No	Yes, < 0.5 feet	Yes, > 0.5 feet		
Does the culvert have wing walls?	No	Yes			

Structure Approximate Dimensions (functional dimensions if partiall

Are the distances measured for the whole structure or for a single chamber of a multispan structure? Whole Structure Single Chamber

For each measurement, indicate 'actual' or 'estimated' measurement with an 'x' in the appropriate column. Actual Estimated

-Height/Rise (feet) – can be marked as graduated	____________		
-Width/Span (feet) – across or span of bridge/culvert along road	____________		
-Length (feet) – for animal crossing over/under road	____________		

Obstructions

Is the immediate entrance blocked?	None	Cattle Fence	Boulders humans would have to climb over	
	Rocks/Riprap (> volleyball size)	Rocks/Riprap (> baseball size)	Some rocks, not continuous	
	Thick Vegetation	Gate	Other:	
Are there structures that block the entrance within 25 feet?		No	Cattle Fence	Small Mesh Fence
		Boulder Field	Stream Flow	High/Steep Cut or Fill Slope

Fill Slope

Is the structure located in a fill slope?	No	Yes, < 20' high	Yes, > 20' high
-If yes, how is the structure situated in the slope?	At the base	Midway on fill slope	Near top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the outlet?	No	Yes, partially	Yes, completely
-If yes, select predominant type:	Grasses	Bushes	Bushes/Trees
Is there vegetation/cover within 25-50' of the outlet?	No	Yes, partially	Yes, completely
-If yes, select predominant type:	Grasses	Bushes	Bushes/Trees

Land Use Within 100 feet of outlet:

Predominant land use:	Forest	Prairie/Grassland	Agriculture	Wetlands
Shrub/Steppe	Mixed: Human/Natural	Residential	Commercial	Other:

Noise

What does passing traffic sound like at the entrance to the structure?

Silent	Low Rumble	Loud and Jarring

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?

	0'	0-6'	6-30'	Undetermined
Is there a guard rail or jersey wall above the structure?	No	Yes, structure only	Yes, extensive	

Notes:

Fencing/Walls (East/South Structure)

Photo Number 1: 2: 3: 4:

Is there fencing present on the East/South side of the structure? Yes No

Select type of fencing to *right* when facing structure: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-If curb or wall, does it have a lip? Yes No

-What is the height of fencing/wall? None ≤ 6" > 6" to ≤2' 2' to 4' 4 to 6' 6 to 8' >8'

-What is the mesh size? None 6x6" 6x6”, graduating smaller to 2x3 at base Other:

-Is it connected to the structure? Yes No - small gap (≤0.5') No - large gap (>0.5')

-Does the fencing reach all the way to ground level without gaps? Yes No

-Is the fencing entrenched in the ground to prevent animals from digging under it? Yes No

- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure? Yes No

If no, what is the ROW fencing type: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-Minimum distance fence extends from structure:

≤ 10 feet 10-50 feet 50-100 feet >100 feet ~½ mile 1 mile Miles End not visible/known

Select type of fencing to *left* when facing structure: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-If curb or wall, does it have a lip? Yes No

-What is the height of fencing/wall? None ≤ 6" > 6" to ≤2' 2' to 4' 4 to 6' 6 to 8' >8'

-What is the mesh size? None 6x6" 6x6”, graduating smaller to 2x3 at base Other:

-Is it connected to the structure? Yes No - small gap (≤0.5') No - large gap (>0.5')

-Does the fencing reach all the way to ground level without gaps? Yes No

-Is the fencing entrenched in the ground to prevent animals from digging under it? Yes No

- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure? Yes No

If no, what is the ROW fencing type: Curb (not including wingwalls) Wall (not including wingwalls)

Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:

-Minimum distance fence extends from structure:

≤ 10 feet 101 feet 120-250 feet ¼ mile ½ mile 2 mile Miles End not visible/known

What is the general condition of the fencing? Gaps and areas where fence is down Some tacking up of fence needed

Vegetation needs to be cleared from fence Fence in good working order

Is there an escape ramp(s) within a 1/2 mile of the structure in either direction? No Yes - 1 Yes - 2 or more

Is there a one-way gate(s) within a 1/2 mile of the structure in either direction? No Yes - 2 Yes - 2 or more

Are there uncontrolled driveways or intersectionsthat cause breaks in the fencing within a 1/2 mile of the structure in either direction?

None 1 2-5 6-10 >10

Notes:

Median

Photo Number 1: 2: 3: 4:

Is there an open median? Yes No

[Include checkbox for each measurement below - Actual Measurements?}

-What is the length of the median (distance between the two structures)? ____________

What is the substrate of the median? Concrete/Asphalt Mix: Man-made & Natural Natural

[if substrate = natural] Is there vegetation in the median? No Yes, partially Yes, completely

-If yes, select predominant type: Grasses Bushes Bushes/Trees

Is their median fencing/walls to prevent animals from accessing the highway via the median? Yes No

-Select type of fencing Curb (not including wingwalls) Wall (not including wingwalls) 4-Strand Wire Chain Link Wildlife Fence Sediment Fence

What is the general condition of the fencing? Gaps and areas where fence is down Some tacking up of fence needed Vegetation needs to be cleared from fence Fence in good working order

Notes:

General

Photo Number 1: 2: 3: 4:

Wildlife Use

Are there signs of wildlife use in the structure such as tracks? Tracks Scat Live Animal None Other (text)

-If yes, describe

Are there signs of wildlife within 30 feet of the entrances? Tracks Scat Roadkill Live Animal None Other (text)

-If yes, describe

Human Use

Is there apparent human activity in the structure? Yes - Frequent/Daily Yes - Occasional No evidence Found

-What type(s) of activity? (check all that apply): Camping/Occupancy Vehicle/ATV use Trail Recreation Dog Night Use Other:

Which description best matches human activities immediately adjacent to the structure?

Daily human activity at both entrances Daily human activity at one entrance Recreational use in a wild setting Wild setting with infrequent human activity Other:

Notes:

Species Movement Guild Rankings

When ranking the structure, consider how changes in water levels and vegetation growth may affect passage for each Species Movement Guild.

A = This animal could make it though as is, or with small modifications
C = With modest modifications this structure could be functional
F = Can't be fixed with a retrofit

Rate this structure for *Low Mobility Small Fauna*, e.g., slow-moving animals that require a consistent environmental conditions, such as frogs or salamanders:

A C F

Comments:

Rate this structure for *Moderate Mobility Small Fauna*, e.g., small animals that are fairly adaptable, such as squirrels, skunks, raccoons, fishers and some turtles:

A C F

Comments:

Rate this structure for *Adaptive High Mobility Fauna*, e.g., fairly tolerant medium-sized animals, such as bobcat, coyote and black bear:

A C F

Comments:

Rate this structure for *High Openness High Mobility Carnivores*, e.g., larger animals that prefer larger structures, such as grizzly bear or mountain lion

A C F

Comments:

Rate this structure for *Adaptive Ungulates*, e.g., ungulates that require good visibility through a structure, such as deer, moose or mountain goats:

A C F

Rate this structure for *Very High Openness Fauna*, e.g., animals that require large structures with clear lines of sight that are less than 100' long, such as elk, pronghorn and turkey:

A C F

Comments:

Which features could be changed to make the structure more functional for each target Species Movement Guild given an A or C rank?

PASSAGE ASSESSMENT SYSTEM: UNDIVIDED HIGHWAY

Preliminary Questions (i.e., fatal flaws)

Assess each of the following questions relative to the species guild of interest to determine whether the structure is fatally flawed for members of the Species Movement Guilds indicated:

Is the structure longer than 300 feet? (fatal flaw for *Adaptive Ungulates* and *Very High Openness Fauna*)	No (continue)	Yes (structure is not suitable for enhancement)
Is the culvert slope > 30 degrees and 100' or longer? (fatal flaw for *all* Species Movement Guilds)	No (continue)	Yes (structure is not suitable for enhancement)
Is there extensive development/pavement in the immediate vicinity of one or both sides of the structure? (fatal flaw for *all* Species Movement Guilds)	No (continue)	Yes (structure is not suitable for enhancement)
Can you see through the structure to the other (for divided highways, consider each structure individually)? (if no, fatal flaw for *Adaptive Ungulates*, *Very High Openness Fauna* and *High Openness High Mobility Carnivores*)	Yes (continue)	No (structure is not suitable for enhancement)

Structure

What is the shape of the structure? Round Pipe | Squash Pipe | Box Culvert | Arch Culvert | Bridge Underpass - sloped | Bridge Underpass - straight | Bridge Overpass | Other (text)

What is the structure material? Concrete | Metal | Plastic/Fiberglass | Other (text)

[If Shape = Box] Are there multiple chambers? No | Yes - # of Chambers? (num)

**If Yes, select the most appropriate chamber for terrestrial passage to answer the following questions.

[If Shape = Bridge Underpass] Is this a single span or multispan structure? Single span | Multispan (1 or more supports)

**If Multispan, select the most appropriate chamber for terrestrial passage to answer the following questions.

[If Shape = Bridge Underpass] What is the material of the abutments on the West/North side?

Concrete | Concrete/Soil | Soil | Riprap | Gabian Wall | Other (txt)

-What is the slope ratio? (horizontal:vertical) 0:1 | 1:1 | 2:1

[If Shape = Bridge Underpass] What is the material of the abutments on the East/South side?

Concrete | Concrete/Soil | Soil | Riprap | Gabian Wall | Other (txt)

-What is the slope ratio? (horizontal:vertical) 0:1 | 1:1 | 2:1

Road Attributes

Number of lanes of road: ___________

Is there parallel infrastructure such as railroads, recreational paths, frontage roads, etc? No | Yes - Describe:

Notes:

INLET SIDE

Photo Number 1: 2: 3: 4:

Is there an apron at the inlet? No Yes, metal Yes, concrete

Does the culvert have wing walls? No Yes

Structure Approximate Dimensions (functional dimensions if partial)

Are the distances measured for the whole structure or for a single chamber of a multispan structure? Whole Structure Single Chamber

For each measurement, indicate 'actual' or 'estimated' measurement with an 'x' in the appropriate column. Actual Estimated

- -Height/Rise (feet) – can be marked as graduated __________
- -Width/Span (feet) – across or span of bridge/culvert along road __________
- -Length (feet) – for animal crossing over/under road __________

Obstructions

Is the immediate entrance blocked? None Cattle Fence Boulders humans would have to climb over
Rocks/Riprap (> volleyball size) Rocks/Riprap (> baseball size) Some rocks, not continuous
Thick Vegetation Gate Other:

Are there structures that block the entrance within 25 feet? No Cattle Fence Small Mesh Fence
Boulder Field Stream Flow High/Steep Cut or Fill Slope

Fill Slope

Is the structure located in a fill slope? No Yes, < 20' high Yes, > 20' high
-If yes, how is the structure situated in the slope? At the base Midway on fill slope Near top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the inlet? No Yes, partially Yes, completely
-If yes, select predominant type: Grasses Bushes Bushes/Trees

Is there vegetation/cover within 25-50' of the inlet? No Yes, partially Yes, completely
-If yes, select predominant type: Grasses Bushes Bushes/Trees

Land Use Within 100 feet of inlet:

Predominant land use: Forest Prairie/Grassland Agriculture Wetlands
Shrub/Steppe Mixed: Human/Natural Residential Commercial Other:

Noise

What does passing traffic sound like at the entrance to the structure?
Silent Low Rumble Loud and Jarring

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?
0' 0-6' 6-30' Undetermined

Is there a guard rail or jersey wall above the structure? No Yes, structure only Yes, extensive

Notes:

Inlet Side: Fencing/Walls

Photo Number 1: 2: 3: 4:

Is there fencing associated with the inlet side of the structure? Yes No

Select type of fencing to *right* when facing structure: Curb (not including wingwalls) Wall (not including wingwalls)
Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:
-If curb or wall, does it have a lip? Yes No
-What is the height of fencing/wall? None ≤ 6" > 6" to ≤2' 2' to 4' 4 to 6' 6 to 8' >8'
-What is the mesh size? None 6x6" 6x6”, graduating smaller to 2x3 at base Other:
-Is it connected to the structure? Yes No - small gap (≤0.5') No - large gap (>0.5')
-Does the fencing reach all the way to ground level without gaps? Yes No
-Is the fencing entrenched in the ground to prevent animals from digging under it? Yes No
- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure? Yes No
If no, what is the ROW fencing type: Curb (not including wingwalls) Wall (not including wingwalls)
Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:
-Minimum distance fence extends from structure:
≤ 10 feet 10-50 feet 50-100 feet >100 feet ~½ mile 1 mile Miles End not visible/known

Select type of fencing to *left* when facing structure: Curb (not including wingwalls) Wall (not including wingwalls)
Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:
-If curb or wall, does it have a lip? Yes No
-What is the height of fencing/wall? None ≤ 6" > 6" to ≤2' 2' to 4' 4 to 6' 6 to 8' >8'
-What is the mesh size? None 6x6" 6x6”, graduating smaller to 2x3 at base Other:
-Is it connected to the structure? Yes No - small gap (≤0.5') No - large gap (>0.5')
-Does the fencing reach all the way to ground level without gaps? Yes No
-Is the fencing entrenched in the ground to prevent animals from digging under it? Yes No
- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure? Yes No
If no, what is the ROW fencing type: Curb (not including wingwalls) Wall (not including wingwalls)
Chain Link Wildlife Fence Sediment Fence 4-Strand Wire Other:
-Minimum distance fence extends from structure:
≤ 10 feet 101 feet 120-250 feet ¼ mile ½ mile 2 mile Miles End not visible/known

What is the general condition of the fencing? Gaps and areas where fence is down Some tacking up of fence needed
Vegetation needs to be cleared from fence Fence in good working order

Is there an escape ramp(s) within a 1/2 mile of the structure in either direction? No Yes - 1 Yes - 2 or more

Is there a one-way gate(s) within a 1/2 mile of the structure in either direction? No Yes - 2 Yes - 2 or more

Are there uncontrolled driveways or intersectionsthat cause breaks in the fencing within a 1/2 mile of the structure in either direction?
None 1 2-5 6-10 >10

Notes:

INSIDE STRUCTURE

Photo Number 1: 2: 3: 4:

Visibility

Does the inside of the structure appear much darker than the outside lighting? High Contrast Low Contrast

Is there a clear line of sight from one end of the structure(s) to the other? No Obscured Yes, complete visibility

Water Features

Is there perennial water flow through structure? No < 3' deep 3-10' deep >10' deep

Does there appear to be a dry natural substrate/dirt pathway through the structure during average flows?
None Dry Dirt Pathway Rock/Dirt Pathway Dry Rocky Pathway

Is there evidence that the dry pathway may be obliterated seasonally or during high water events?
No Yes Uncertain

Substrate

What is the substrate of the floor at the bottom/center of the structure? Concrete/Asphalt Metal
Plastic Rocks Dry Soil Stream Bottom Other (txt)

-Is there a natural bottom through the length of the structure? Yes No

-Is there a natural bottom across the width of the structure? Yes No, > 6" No, 6" or greater

Pathway Floor Substrate

Does the substrate through the structure appear similar to substrate outside of the structure? Yes No

-If No, what is the floor substrate?
Concrete Concrete with Steel Riprap (> baseball) Riprap (> volleyball) Boulders Other (text)

-If Yes, what is the minimum width of the dry natural pathway all the way through the structure?
<2 feet 2-5 feet 5-10 feet 10-20 feet 20-50 feet Over 50 feet

Vegetation

Is there vegetative cover and/or woody debris through the structure? None Some Logs, Down Trees
Some Grass/Brush Grasses Brush/Bushes/Trees

Noise

What does passing traffic sound like from the middle of the structure?
Silent Low Rumble Loud and Jarring

Other

Is there a road or trail through the structure? None Paved Road Dirt Road Railroad Paved Trail Dirt Trail

Are there obstructions inside the structure? None Debris Soil Baffles Gaps/Trenche Man-made Items

Is there a sky light in structure? No Yes

Notes:

OUTLET SIDE

Photo Number	1:	2:	3:	4:	
Is there an apron at the outlet?	No		Yes, metal	Yes, concrete	
Is the outlet perched?	No		Yes, < 0.5 feet	Yes, > 0.5 feet	
Does the culvert have wing walls?	No		Yes		

Structure Approximate Dimensions (functional dimensions if partial

Are the distances measured for the whole structure or for a single chamber of a multispan structure? Whole Structure Single Chamber

For each measurement, indicate 'actual' or 'estimated' measurement with an 'x' in the appropriate column. Actual Estimated

- -Height/Rise (feet) – can be marked as graduated ____________
- -Width/Span (feet) – across or span of bridge/culvert along road ____________
- -Length (feet) – for animal crossing over/under road ____________

Obstructions

Is the immediate entrance blocked? None | Cattle Fence | Boulders humans would have to climb over

Rocks/Riprap (> volleyball size) | Rocks/Riprap (> baseball size) | Some rocks, not continuous

Thick Vegetation | Gate | Other:

Are there structures that block the entrance within 25 feet? No | Cattle Fence | Small Mesh Fence

Boulder Field | Stream Flow | High/Steep Cut or Fill Slope

Fill Slope

Is the structure located in a fill slope? No | Yes, < 20' high | Yes, > 20' high

-If yes, how is the structure situated in the slope? At the base | Midway on fill slope | Near top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the outlet? No | Yes, partially | Yes, completely

-If yes, select predominant type: Grasses | Bushes | Bushes/Trees

Is there vegetation/cover within 25-50' of the outlet? No | Yes, partially | Yes, completely

-If yes, select predominant type: Grasses | Bushes | Bushes/Trees

Land Use Within 100 feet of outlet:

Predominant land use: Forest | Prairie/Grassland | Agriculture | Wetlands

Shrub/Steppe | Mixed: Human/Natural | Residential | Commercial | Other:

Noise

What does passing traffic sound like at the entrance to the structure?

Silent | Low Rumble | Loud and Jarring

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?

0' | 0-6' | 6-30' | Undetermined

Is there a guard rail or jersey wall above the structure? No | Yes, structure only | Yes, extensive

Notes:

Outlet Side: Fencing/Walls

Photo Number		1:		2:		3:		4:
Is there fencing associated with the outlet side of the structure?					Yes	No		
Select type of fencing to *right* when facing structure:				Curb (not including wingwalls)			Wall (not including wingwalls)	
	Chain Link		Wildlife Fence		Sediment Fence		4-Strand Wire	Other:
-If curb or wall, does it have a lip?				Yes	No			
-What is the height of fencing/wall?			None	≤ 6"	> 6" to ≤2'	2' to 4'	4 to 6'	6 to 8'	>8'
-What is the mesh size?		None		6x6"		6x6”, graduating smaller to 2x3 at base		Other:
-Is it connected to the structure?			Yes		No - small gap (≤0.5')		No - large gap (>0.5')	
-Does the fencing reach all the way to ground level without gaps?					Yes	No		
-Is the fencing entrenched in the ground to prevent animals from digging under it?						Yes	No	
- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure?							Yes	No
	If no, what is the ROW fencing type:			Curb (not including wingwalls)			Wall (not including wingwalls)	
	Chain Link		Wildlife Fence		Sediment Fence		4-Strand Wire	Other:
-Minimum distance fence extends from structure:								
	≤ 10 feet	10-50 feet	50-100 feet	>100 feet	~½ mile	1 mile	miles	end not visible/known
Select type of fencing to *left* when facing structure:				Curb (not including wingwalls)			Wall (not including wingwalls)	
	Chain Link		Wildlife Fence		Sediment Fence		4-Strand Wire	Other:
-If curb or wall, does it have a lip?				Yes	No			
-What is the height of fencing/wall?			None	≤ 6"	> 6" to ≤2'	2' to 4'	4 to 6'	6 to 8'	>8'
-What is the mesh size?		None		6x6"		6x6”, graduating smaller to 2x3 at base		Other:
-Is it connected to the structure?			Yes		No - small gap (≤0.5')		No - large gap (>0.5')	
-Does the fencing reach all the way to ground level without gaps?					Yes	No		
-Is the fencing entrenched in the ground to prevent animals from digging under it?						Yes	No	
- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure?							Yes	No
	If no, what is the ROW fencing type:			Curb (not including wingwalls)			Wall (not including wingwalls)	
	Chain Link		Wildlife Fence		Sediment Fence		4-Strand Wire	Other:
-Minimum distance fence extends from structure:								
	≤ 10 feet	101 feet	120-250 feet	¼ mile	½ mile	2 mile	miles	end not visible/known
What is the general condition of the fencing?				Gaps and areas where fence is down			Some tacking up of fence needed	
			Vegetation needs to be cleared from fence				Fence in good working order	
Is there an escape ramp(s) within a 1/2 mile of the structure in either direction?						No	Yes - 1	Yes - 2 or more
Is there a one-way gate(s) within a 1/2 mile of the structure in either direction?						No	Yes - 2	Yes - 2 or more

Are there uncontrolled driveways or intersections that cause breaks in the fencing within a 1/2 mile of the structure in either direction?

None	1	2-5	6-10	>10

Notes:

General

Photo Number 1: 2: 3: 4:

Wildlife Use

Are there signs of wildlife use in the structure such as tracks? Tracks Scat Live Animal None Other (text)

-If yes, describe

Are there signs of wildlife within 30 feet of the entrances? Tracks Scat Roadkill Live Animal None Other (text)

-If yes, describe

Human Use

Is there apparent human activity in the structure? Yes - Frequent/Daily Yes - Occasional No evidence Found

-What type(s) of activity? (check all that apply): Camping/Occupancy Vehicle/ATV use Trail Recreation Dog Night Use Other:

Which description best matches human activities immediately adjacent to the structure?

Daily human activity at both entrances Daily human activity at one entrance

Recreational use in a wild setting Wild setting with infrequent human activity Other:

Notes:

Species Movement Guild Rankings

When ranking the structure, consider how changes in water levels and vegetation growth may affect passage for each Species Movement Guild.

A = This animal could make it though as is, or with small modifications

C = With modest modifications this structure could be functional

F = Can't be fixed with a retrofit

Rate this structure for *Low Mobility Small Fauna*, e.g., slow-moving animals that require a consistent environmental conditions, such as frogs or salamanders:

A C F

Comments:

Rate this structure for *Moderate Mobility Small Fauna*, e.g., small animals that are fairly adaptable, such as squirrels, skunks, raccoons, fishers and some turtles:

A C F

Comments:

Rate this structure for *Adaptive High Mobility Fauna*, e.g., fairly tolerant medium-sized animals, such as bobcat, coyote and black bear:

A C F

Comments:

Rate this structure for *High Openness High Mobility Carnivores*, e.g., larger animals that prefer larger structures, such as grizzly bear or mountain lion

A C F

Comments:

Rate this structure for *Adaptive Ungulates*, e.g., ungulates that require good visibility through a structure, such as deer, moose or mountain goats:

A C F

Comments:

Rate this structure for *Very High Openness Fauna*, e.g., animals that require large structures with clear lines of sight that are less than 100' long, such as elk, pronghorn and turkey:

A C F

Comments:

Which features could be changed to make the structure more functional for any Species Movement Guild given an A or C rank?

User's Guide to Passage Assessment System

This User's Guide is a *reference document* to assist users of the Passage Assessment System. For each structure that is being evaluated, the user will complete (1) General Assessment Questions, and (2) Divided *or* Undivided Highway Assessment Questions, depending on whether the structure is located on a divided or undivided highway. Each of the questions in these sections are fully explained in this User's Guide.

MATERIALS:
Clipboard, GPS unit, camera, 200' measuring tape

Special Note About Seasonality and Using the PAS: The time of year at which the PAS is conducted can greatly later perspectives on the functionality of the structure for a given Species Movement Guild because of changes in water flows in different seasons. At locations where terrestrial passage may be significantly affected by changes in water levels, it is recommended that the PAS be conducted two or more times throughout the year to more accurately capture the impacts on terrestrial passage through the structure. Multiple assessments can also provide additional information relating to changes in vegetation growth and signs of animal activity throughout the year.

Special Note About Urban Environments: The Passage Assessment System was developed for the purpose of assessing highway infrastructure located in non-urban environments. This evaluation system may also be applied to structures located in urban environments, however, users should be aware that urban wildlife are more adapted to human activity and infrastructure than their non-urban counterparts and may, therefore, have different tolerances for which the user will need to account when developing enhancement solutions.

TAB 1: GENERAL QUESTIONS

This form should be completed for each structure being evaluated.

Date:	Today's date (dd/mm/yyyy)
Location ID:	Unique location number assigned to a given structure during a given field session (i.e., 01, 02, 03, etc)
Location Code:	Unique identifier code for a given structure written as: route number_milepost_location id (e.g., 90_234_07 for US90, MP 234, Location #7)
Route #:	Highway number (e.g. US 101)
Milepost:	Milepost number to the nearest tenth mile
GPS ID:	Record ID number automatically generated by the GPS unit
GPS Latitude:	Derived from the GPS unit
GPS Longitude:	Derived from the GPS unit
Structure Functional Class:	Select the appropriate Functional Class of the structure being evaluated: 1 = small underpass (<5' span); 2 = medium underpass (5-8' span x 8' rise); 3 = large underpass (≥ 20' span x 8' rise, or ≥ 10' span x 10' rise) ; 4 = extensive bridge; 5 = wildlife overpass; 6 = specialized culverts; 7 = canopy bridge. Refer to the document *Functional Classes of Structures* for complete descriptions.
Species Movement Guild:	Identify the Species Movement Guilds that have been identified for this location (select all that apply): Low Mobility Fauna; Moderate Mobility Small Fauna; Adaptive High Mobility Fauna; High Openness High Mobility Fauna; Adaptive Ungulates; Very High Openness Fauna; Arboreal Fauna; Aerial Fauna. Refer to the document *Terrestrial Species Guilds* for complete descriptions.
Bridge Number:	WSDOT identification number
Divided or Undivided:	Note if the highway along this segment is divided or undivided at the point of the structure being evaluated.
Highway Direction:	Note if the primary direction of the roadway is east-west or north-south.
Roadway Photo Numbers:	Enter photo id numbers. Pictures are extremely helpful - take a lot!

TAB 2 or 3: DIVIDED OR UNDIVIDED HIGHWAY

Select the appropriate form for evaluating a given structure based on whether the structure is at a divided or undivided highway. *While the questions posed are the same for a divided or undivided highway, they must be posed independently for each structure at a divided highway site. Evaluation questions are divided into distinct sections to guide the evaluation process. Some questions are repeated to capture conditions on both sides of a structure.*

Preliminary Questions

These are a collection of targeted questions designed to determine if there is a 'fatal flaw' with the structure relative to the Species Movement Guild(s) of interest. Each question should be considered relative to the Species Movement Guilds indicated. If a fatal flaw is identified, then the user need not complete all of the Passage Evaluations System questions as the fatal flaw renders the structure unsuitable for a enhancement; a redesigned and reconstructed structure is required to pass wildlife at that location.

Is the structure longer than 300 feet?	A 'Yes' response is considered a fatal flaw for *Adaptive Ungulates* and *Very High Openness Fauna* and the structure is not suitable for enhancements. If the response is 'No', the user continues with the evaluation.
Is the culvert slope > 30 degrees and 100' or longer?	A 'Yes' response is considered a fatal flaw for all *Species Movement Guilds* and the structure is not suitable for enhancement. If the response is 'No', the user continues with the evaluation. This threshold is intended as a general guideline; it may be adjusted based on additional research or local expertise.
Is there extensive human development/pavement in the immediate vicinity of one or both sides of the structure?	A 'Yes' response is considered a fatal flaw for *all* Species Movement Guilds and the structure is not suitable for enhancement. While structures in a developed landscape may pass some animals that have adapted to that landscape, these structures offer limited use for passing wildlife populations and improving connectivity. If the response is 'No', the user continues with the evaluation.
Can you see through the structure to the other side (for divided highways, consider each structure individually)?	A 'No' response is considered a fatal flaw for several species guilds and the structure is not suitable for enhancement. If the response is 'No', the user continues with the evaluation.

Structure

What is the shape of the structure?	Select one: Round Pipe, Squash Pipe, Box Culvert, Arch Culvert, Bridge Underpass with sloped sides, Bridge Underpass with straight sides, Bridge Overpass or Other (describe).
What is the structure material?	Refers to the material used to construct the structure, on the inside of the structure that an animal passing through would experience. This question does not refer to the presence of natural or deposited sediment on the floor of the structure. Select one: Concrete, Metal, Plastic/Fiberglass

[If Shape = Box] Are there multiple chambers?	If the structure is a box culvert, the user is prompted to answer this question. Multiple chambers occur if the box has one or more divisions, resulting in discrete chambers. If the response is yes, there are multiple chambers, then the user if prompted to select the most appropriate chamber for responding to all subsequent questions (e.g., the largest or driest chamber)
[If Shape = Bridge Underpass] Is this a single span or multispan structure?	If the structure is a Bridge Underpass, the user is prompted to answer this question. A single span bridge has supports only at either end of the structure; a multispan bridge has one or more supports at intervals along the length of the structure.
[If Shape = Bridge Underpass] What is the material of the abutments on the West/North side?	If the structure is a Bridge Underpass, the user is prompted to answer this question. Select one: Concrete, Concrete/Soil mix; Soil, Riprap, Gabian Wall, or Other (describe)
-What is their ratio?	What is the approximate ratio of the side slope on the West or North side of the structure?
[If Shape = Bridge Underpass] What is the material of the abutments on the East/South side?	If the structure is a Bridge Underpass, the user is prompted to answer this question. Select one: Concrete, Concrete/Soil mix; Soil, Riprap, Gabian Wall, or Other (describe)
-What is the slope ratio?	0:1 = vertical; 1:1 = 45° angle; 2:1 = gentle low slope

Road Attributes

Number of lanes of road:	Enter the total number of lanes, in both travel directions, including center lanes and turning lanes. Do not include highway exits or frontage roads.
Is there parallel infrastructure such as railroads, recreational paths, frontage roads, etc?	Describe any additional transportation infrastructure adjacent to the roadway.
Notes:	Provide any additional information about the structure or its situation in the surrounding environment that is not covered elsewhere.

INLET/OUTLET SIDE

For sites without water flow through the structure, the user should designate the uphill side as the inlet and the downhill side as the outlet. At locations where an uphill and downhill side cannot be distinguished, the user should simply designate one entrance to represent the inlet and the other the outlet.

Photo Number:	Enter photo id numbers. Pictures are extremely helpful - take a lot!
Is there an apron at the inlet/outlet?	Yes or No. If yes, indicate whether metal or concrete
Does the culvert have wing walls?	Yes or No

Is the outlet perched?	A perched outlet refers to a culvert whose base is perched above the ground level. This situation often occurs with pipes either by design, or because the ground immediately beneath the culvert has eroded.

Structure Approximate Dimensions **(functional dimensions if partially buried)**

Actual or Estimated Measurements?	Indicate whether the structure was measured precisely or if the measurements were estimated.
-Height/Rise (feet):	Measure the height of the structure in feet
-Width/Span (feet):	Measure the width (span) of the structure in feet. Refers to the width of the structure from the perspective of an animal passing through.
-Length (feet):	Measure the length of the structure in feet. Refers to the length of the structure from the perspective of an animal passing through.

Obstructions

Is the immediate entrance blocked?	Are there physical barriers at the immediate entrance that may block entry for target species that may try to enter the structure? Select one: None, Cattle Fence (4-strand barbed wire), Boulders so big a human would have to climb over them, Riprap larger than a volleyball, Riprap larger than a baseball, Some rocks (not continuously blocking the entrance), Thick Vegetation, Gate, or Other (describe).
Are there structures that block the entrance within 25 feet?	Are there physical barriers within 25 feet that may block passage through the structure? Select one: None, Cattle Fence, Small Mesh Fence, Boulder Field, Stream Flow, High/Steep Cut or Fill Slope.

Fill Slope

Is the structure located in a fill slope?	Select one: No or Yes. If yes, is the slope less than 20' high or greater than or equal to 20' high?
-If yes, how is the structure situated in the slope?	Note the location of the structure relative to the fill slope. Select one: At the base; Midway on fill slope; or Near the top of fill slope

Approach Vegetation & Cover

Is there vegetation/cover within 25' of the inlet?	Select one: No, Yes - partial cover, or Yes - complete cover
-If yes, select predominant type:	Select one: Grasses, Bushes, Bushes/Trees mix
Is there vegetation/cover within 25-50' of the inlet?	Select one: No, Yes - partial cover, or Yes - complete cover
-If yes, select predominant type:	Select one: Grasses, Bushes, Bushes/Trees mix

Land Use Within 100 feet

Predominant land use:	Select the predominant land use within 100 feet of the structure entrance: Forest, Prairie/Grassland, Agriculture, Wetlands, Shrub/Steppe, Mixed Human/Natural, Residential, Commercial, or Other

Noise

What does passing traffic sound like at the entrance to the structure?	Loud traffic noise at the entrance to a structure my deter passage use by some species. Select one of the following to best characterize how passing traffic sounds when standing in front of the entrance to a structure: Silent; Low Rumble; or Loud and Jarring.

Road Attributes

How wide is zone of maintained vegetation (allowing extra visibility along the road shoulder)?	This refers to the portion of the right-of-way that is maintained to keep it clear of high vegetation and other obstructions. Note the approximate width of the apparent zone of maintained vegetation to the left and right of the structure.
Is there a guard rail or jersey wall above the structure?	No, Yes - immediately above the structure only, or Yes - extensive along the roadway segment

Notes:

INSIDE STRUCTURE

Photo Number:	Enter photo id numbers. Pictures are extremely helpful - take a lot!

Visibility

Does the inside of the structure appear much darker than the outside lighting?	Note High or Low Light Contrast. In some cases, animals (e.g., ungulates) may be deterred from structures where the lighting inside the structure contrasts significantly with the lighting outside the structure.
Is there a clear line of sight from one end of the structure(s) to the other?	A clear sight line means that you have visibility from one end of the structure to the other. Some wildlife have a higher tendency to use structures with clear lines of sight than those they cannot see the open area out the other end. Note if the line of sight is completely clear, partially obscured, or completely obscured.

Water Features

Is there perennial water flow through structure?	Note the depth of perennial water flow through the structure: None; < 3' deep; 3-10' deep; or >10' deep
Does there appear to be a dry natural substrate/dirt pathway through the structure during average flows?	A dry, natural pathway through a structure from one end to the other is important to structure functionality for a number of terrestrial species. Select one: None, Dry Dirt Pathway, Rock/Dirt Pathway, or Dry Rocky Pathway.
Is there evidence that the dry pathway may be obliterated seasonally or during high water events?	The purpose of this question is to determine whether there are certain time periods when a structure may become unusable for certain species due to high water. Select: No, Yes, or Uncertain.

Substrate

What is the substrate of the floor at the bottom/center of the structure?	Select one: Concrete/Asphalt, Metal, Plastic, Rocks, Soil, Stream Bottom, or Other (describe).
-Is there a natural bottom through the length of the structure?	Does a natural surface (non-manmade) extend the full length of the structure, for as least some portion of the width of the structure? Answer Yes or No.
-Is there a natural bottom across the width of the structure?	Does a natural surface (non-manmade) extend across the entire width or some portion of the width of the structure? Answer Yes, No - less than 6"; No - 6" or greater

Pathway Floor Substrate

Does the substrate through the structure appear similar to substrate outside of the structure?	Yes or No.
-If No, what is the floor substrate?	Select one: Concrete, Concrete with Baffles/Stabilizers, Steel, Riprap greater than a baseball, Riprap greater than a volleyball, Boulders, or Other (describe)
-If Yes, what is the minimum width of the dry natural pathway all the way through the structure?	Select one: <2 feet; 2-5 feet; 5-10 feet; 10-20 feet; 20-50 feet; or Over 50 feet

Vegetation

Is there vegetative cover and/or woody debris through the structure?	Vegetation in a structure may provide protective cover which can encourage use by some species. Select one: None; Some Logs or Down Trees; Some Grass/Brush; Grasses; Mix of Brush/Bushes/Trees.

Noise

What does passing traffic sound like from the middle of the structure?	A broad, subjective assessment of traffic noise levels for animals crossing through the structure. Question does not consider traffic volumes. Select one: Silent; Low Rumble; or Loud and Jarring

Other

Is there a road or trail through the structure?	Select all that apply: None, Paved Road, Dirt Road, Railroad, Paved Trail, Dirt Trail.
Are there obstructions inside the structure?	Indicate whether there are any features that could obstruct movement through the structure for the Species Guilds of interest. Select all that apply: None, Natural Debris, Soil, Human Structures/Equipment, Gaps/Trenches, Baffles.
Is there a sky light in structure?	Yes or No

Notes:

Fencing/Walls (completed for both inlet and outlet sides of the structure)

Photo Number:	Enter photo id numbers. Pictures are extremely helpful - take a lot!
Is there fencing associated with the structure?	Yes or No
Select type of fencing to *right/left* when facing structure:	These questions apply to the fencing only, they do not apply to structure wingwalls. Select one: Curb (short wall to guide amphibians), Wall, Chain Link Fence, Wildlife Fence, Sediment Fence, 4-Strand Wire Fence, or Other (specify).
-If curb or wall, does it have a lip?	Yes or No. (A lip inhibits animals from climbing over the wall)
-What is the height of fencing/wall?	Select one: ≤ 6"; > 6" to ≤2'; 2' to 4'; 4 to 6'; 6 to 8', >8'
-What is the mesh size?	Mesh size refers to the spacing of the fence strands. Small animals may be able to pass through larger mesh sizes. Select one: None; 6x6"; 6x6", graduating smaller to 2x3 at base; Other (describe)
-Is it connected to the structure?	Note if there are gaps between the structure and the start of the fencing or wall, where an animal may be able to pass through. Select one: Yes, No - small gap (≤0.5'), No - large gap (>0.5')
-Does the fencing reach all the way to ground level without gaps?	Yes or No. Animals may be able to pass underneath fencing if it does not extend to ground level along the full length of the fencing.
-Is the fencing entrenched in the ground to prevent animals from digging under it?	Yes or No. Digging animals may be able to pas underneath fencing that is not entrenched into the ground.
- Is the ROW fencing the same as the fencing that is immediately adjacent to the structure?	Yes or No. If no, what is the ROW fencing type: Curb (not including wingwalls); Walls (not including wingwalls); Chain Link; Wildlife Fence; Sediment Fence; 4-Strand Wire; or Other (specify).
-Minimum distance fence extends from structure:	This question characterizes the purpose of the fencing as guide fencing or continuous fencing along a segment of roadway. Select the option that best approximates the length of the fencing: ≤ 10 feet; 10-50 feet; 50-100 feet; >100; ~1/2 mile; miles (may be determined if the user has driven a long segment of roadway); or end not known or visible.
What is the general condition of the fencing?	The condition of fencing is important to capture in the evaluation as poorly maintained fencing with gaps may allow animals to pass through and become trapped inside the right-of-way. Select all that apply: Gaps and areas where fence is down; Some tacking up of fence needed; Vegetation needs to be cleared from fence; Fence in good working order.
Is there an escape ramp(s) within a 1/2 mile of the structure in either direction?	Escape ramps are designed to allow ungulates (in particular) and other large mammals that have become trapped inside the right-of-way to escape back to the other side of the fencing. Indicate if ramps are present along the fencing: No; Yes - 1; Yes - 2 or more.

Is there a one-way gate(s) within a 1/2 mile of the structure in either direction?	One-way gates are a previously-used mechanism for allow ungulates that have become trapped inside the right-of-way to escape back to the other side of the fencing, however they are difficult to maintain and often themselves become gaps in the fencing. Their installation is no longer recommended as an effective mitigation measure. Indicate if ramps are present along the fencing: No; Yes - 1; Yes - 2 or more.
Are there uncontrolled driveways, intersections or exit ramps that cause breaks in the fencing within a 1/2 mile of the structure in either direction?	An uncontrolled driveway, intersection or exit ramp is point where there is a break in the fencing to allow vehicular access to adjacent infrastructure that also acts as a gap in the fencing for wildlife. Such breaks may be controlled by double cattle guards, specifically-designed electric mats, gates, or other mechanisms, however controlling these breaks can be expensive if there are multiple breaks in a segment of fencing. Select one: None; 1; 2-5; 6-10; >10
Notes:	Provide any additional information about fe

General

Photo Number:	Enter photo id numbers. Pictures are extremely helpful - take a lot!

Wildlife Use

Are there signs of wildlife use in the structure such as tracks?	Select all that apply: Tracks, Scat, Live Animal, None or Other (describe)
-If yes, describe	Note species, if known, and other pertinent information
Are there signs of wildlife within 30 feet of the entrances?	Select all that apply: Tracks, Scat, Live Animal, None or Other (describe)
-If yes, describe	Note species, if known, and other pertinent information

Human Use

Is there apparent human activity in the structure?	Yes - Frequently/Daily; Yes - Occasional; or No evidence Found
-What type(s) of activity?	Select all that apply: Camping/Occupancy, Vehicle/ATV use, Trail, Recreation, Dog, Night Use, Other
Which description best matches human activities immediately adjacent to the structure?	The purpose of this question is to get a general understanding of human activity - not including permanent development - at the structure, in terms of frequency, location (at one or both entrances) and the setting itself. Select one: Daily human activity at both entrances; Daily human activity at one entrance; Recreational use in wild setting; Wild setting with infrequent human activity; Other.

Notes:

Species Movement Guild Rankings

The following questions are designed to get a general impression while the user is in the field of how functional the structure is for each of the Species Movement Guild of interest. They are subjective and responses should be based on the user's overall impression having completed the rest of the structure assessment. Refer to Species Movement Guilds for complete descriptions.

Each question should be ranked as follows:

A = This animal could make it though as is, or with small modifications
C = With modest modifications this structure could be functional
F = Can't be fixed with a retrofit

Rate this structure for *Low Mobility Small Fauna*, e.g., slow-moving animals that require a consistent environmental conditions, such as frogs or salamanders:

A C F

Rate this structure for *Moderate Mobility Small Fauna*, e.g., small animals that are fairly adaptable, such as squirrels, skunks, raccoons, fishers and some turtles:

A C F

Rate this structure for *Adaptive High Mobility Fauna*, e.g., fairly tolerant medium-sized animals, such as bobcat, coyote and black bear:

A C F

Rate this structure for *High Openness High Mobility Carnivores*, e.g., larger animals that prefer larger structures, such as grizzly bear or mountain lion

A C F

Rate this structure for *Adaptive Ungulates*, e.g., ungulates that require good visibility through a structure, such as deer, moose or mountain goats:

A C F

Rate this structure for *Very High Openness Fauna*, e.g., animals that require large structures with clear lines of sight that are less than 100' long, such as elk, pronghorn and turkey:

A C F

Which features could be changed to make the structure more functional for any Species Movement Guild given an A or C rank?

This question offers an opportunity for the user to suggest potential retrofits to improve the structure functionality. These may, of course, be amended later, but it is often helpful to capture initial impressions and ideas while still in the field.

APPENDIX C. PASSAGE ENHANCEMENT TOOLBOX FOR IMPROVING EXISTING STRUCTURES FOR TERRESTRIAL WILDLIFE

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Remove Obstacles to Wildlife Passage			
Remove obstruction or barrier at one or both structure entrances, inside the structure, or in the approaches to the structure (e.g.,cattle fencing across structure entrances; trash or debris).	Low Mobility Small Fauna Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	ALL	
Clear debris and install sediment traps and/or regularly maintain to prevent structure from being blocked, filled or clogged.	Low Mobility Small Fauna Moderate Mobility Small Fauna Adaptive High Mobility Fauna	Class 1, 2	Yanes, M., J.M. Velasco, and F. Suárez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217-222.
Keep culvert enterances clear of heavy vegetation growth that could block wildlife passage.		Class 1, 2, 3	Clevenger, A.P., B. Chruszcz, and K. Gunson. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal or Applied Ecology 38:1340-1349.

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Facilitate Movement and Create Pathways			
Add a dry, natural pathway through structure, on both sides of waterway if a stream or river is present.	Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	Forman, R. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C. D., Dale, V. H., et al. 2003. Mitigation for wildlife. Pages 139-167 in: Road Ecology: Science and Solutions. Island Press, Washington, D.C.
Minimize or cover riprap on side-slopes with dirt to create a dry, smooth pathway.	Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	
Install interlocking brick to support slopes instead of riprap toopen up a pathway and facilitate wildlife passage.	Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	
Install a raised shelf through water-filled culverts to provide a dry pathway for small mammals; Include a shelf tube to provide protective cover for voles.	Low Mobility Small Fauna	Class 1, 2	
Add baffles to culvert floor to retain sediment on artifical culvert floor (where water flows occasionally through the culvert).	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 1, 2, 3	

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Install woody debris (e.g., down logs) through a structure for small species requiring cover from predators.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 2, 3, 4, 5	Ehinger, W., P. Garvey-Darda, R. Gersib, K. Halupka, P. McQueary, W. Meyer, R. Schanz and P. Wagner. 2006. Interstate 90 Snoqualmie Pass East Mitigation Development Team: Recommendation package. Submitted to: U.S. Department of Transportation, Federal Highway Administration and Washington State Department of Transportation.
Maintain natural streambanks through the structure.	Low Mobility Small Fauna Moderate Mobility Small Fauna (riparian species)	Class 2, 3, 4	
Add a strip of natural substrate and vegetation along one or both sides of a road through a structure.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 3	
Where scour has resulted in perched culverts, build up scour resistant materials to create a navigable pathway into the culvert. Use natural materials; if riprap is used to build up the entrance pathway, it should be covered with natural substrate.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1, 2,	

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Rerrange substrate material around inlet/outlet of small culverts to allow greater visibility through structures.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1	
Add salamander ramps at curbs.	Low Mobility Small Fauna		
Add grates to existing culverts to allow light/moisture/temperature penetration into the culvert.	Low Mobility Small Fauna	Class 1, 6	Carr, T., R. Dacanay, K. Drake, C. Everson, A. Sperry and K. Sullivan. 2003. Wildlife Crossings: Rethinking Road Design to Improve Safety and Reconnect Habitat. Portland State University Planning Workshop, Prepared for Metro. 111 pp.
Modify existing trenched drains to allow animals to enter.	Low Mobility Small Fauna	Class 6	Bank, F.G., C.L. Irwin, G.L. Evink, M.E. Gray, S. Hagood, J.R. Kinar, A. Levy, D. Paulson, B. Ruediger, and R.M. Sauvajot. 2002. Wildlife Habitat Connectivity Across European Highways. Federal Highway Administration. Alexandria, VA. URL: http://international.fhwa.dot.gov/wildlife_web.htm

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
For Multi-chambered structures with waterflow, divert waterflow so that one chamber remains dry for terrestrial wildlife.	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	
Promote waterflow through culverts to prevent standing water from inhibiting passage through a culvert or detering entry into the culvert.	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 1, 2, 3	
Prevent polluting agents and road sediment from being flushed through culverts.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1, 6	
Reduce Intimidation			
Replace steep abutment slopes or walls with natural 2:1 slopes.	Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	Dodd, N.L., J.W. Gagnon, A.L. Manzo, and R.E. Scheinsburg. 2007. Video surveillance to assess highway underpass use by elk in Arizona. Journal of Wildlife Management 71(2):637-645.

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Remove fill predator perches - ledges or places where prey species may be fearful of unseen predators.	Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	Little, S.J., R.G. Harcour, A.P. Clevenger. 2002. Do wildlife passages act as prey-traps? Biological Conservation 107:135-145.
Add median skylights or openings. [This measure is not appropriate for all culvert situations. Avoid creating very high contrast conditions inside the culvert; Avoid where there is a narrow median that would result in a large increase in traffic noise inside the culvert; Avoid allowing precipitation to enter the culvert where winter temperatures could cause the creation of ice mounds inside the culvert, thereby inhibiting wildlife passage].	Adaptive Ungulates Very High Openness Fauna	Class 2	Reed, D.F., T.N.Woodard, T.M. Pojar. 1975. Behavioral Response of Mule Deer to a Highway Underpass. J. Wild Manage. 39(2):361-367.

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Avoid/remove highway lighting near structure entrances.	ALL	ALL	Jackson, S. D. (2000). Overview of Transportation Impacts on Wildlife Movement. Wildlife and Highways: Seeking Solutions to an ecological and Socio-economic Dilemma. T. A. Messmer and B. West, The Wildlife Society.
Implement measures to reduce traffic noise inside culvert and/or at structure entrances (e.g., concrete shoulder barriers placed above the structure)	ALL	ALL	Jackson, S. D. (2000). Overview of Transportation Impacts on Wildlife Movement. Wildlife and Highways: Seeking Solutions to an ecological and Socio-economic Dilemma. T. A. Messmer and B. West, The Wildlife Society.
To the extent possible, avoid laying trails or other human access through crossing structures. Where trails do pass through a structure, separate human trails from wildlife pathways through the structure.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4, 5	Hartmann, M. (2003). Evaluation of Wildlife Crossing Structures: Their Use and Effectiveness.

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Install signs near crossing structures or where trails cross through structures to limit human activity in and around wildlife crossings [Avoid drawing attention to unobtrusive crossing structures with unnecessary signage]	ALL	ALL	Clevenger, A. and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121:453-464.
Install barriers (e.g., large boulders) to prevent motorized travel through crossing structures.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	
Enhance Structure Approaches			
Enhance/maintain native vegetation cover in front of structure entrances.	ALL	ALL	Ng, S., J. Dole, R. Sauvajot, S. Riley, and T. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation 1115:499-507.
Thin heavy vegetation that may obstruct wildlife passage at structure entrances.	Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 2, 3	Maintain a balance between enough cover for prey species to feel safe entering a culvert, but not so much that animals cannot enter or have good visibility into and through the culvert.
Avoid the use of herbicides around structure entrances.	Low Mobility Small Fauna	ALL	

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Plant bushes in the median to provide better cover and insulation from highway traffic noise and lights.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Wherever open median is present	
Avoid the use of erosion netting in landscaping around crossing structures, which may ensnare snakes.	Moderate Mobility Small Fauna	ALL	
Convert cattle fencing near structure approaches to wildlife-friendly rail fencing to allow young to pass through to access structures.	Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	
Fencing and Barriers			
Add wildlife fencing and/or guide walls to existing suitable structures - do not install extensive fencing where there are no suitable crossing structures.	ALL - type, design & height of fencing or guide wall depends on species (see notes)	N/A	For guidance on different types of wildlife fencing, see: http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Funnel_Fencing/Wildlife_Funnel_Fencing_Summary.pdf
Modify existing right-of way fencing by adding height to convert it to wildlife fencing.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	N/A	FHWA. Keeping it Simple - Arizona. http://www.fhwa.dot.gov/environment/wildlifeprotection

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Angle fence ends away from roadway to preven 'end-arounds'.	ALL		Clevenger, A. P., B. Chruszcz, and K. E. Gunson. 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. Wildlife Society.
Do not end fencing in good wildlife habitat; end in transitional areas (e.g., steep terrain, change in habitat or land use).			Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006. Evaluation of wildlife crossing structures and fencing on US Highway 93, Evaro to Polson. Phase I: Preconstruction data collection and finalization of evaluation plan. Final report. Western Transportation Institute, College of Engineering, Montana State University.
Place large boulders at fence ends to prevent animals at-grade crossings at fence ends.	Adaptive Ungulates Very High Openness Fauna	N/A	Clevenger, A.P., B. Chruszcz, K. Gunson, K. and M. Brumfit. 2002. Highway mitigation monitoring: Three Sisters Parkway interchange. Final report, August 1999 - July 2002. Prepared for Alberta Sustainable Resource Development, Canmore, Alberta, Canada.
Install wildlife fencing across a median to adjacent structures.	ALL	N/A	

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Install escape ramps along fenced sections.	Adaptive Ungulates Very High Openness Fauna	N/A	Bissonette, J.A. and M. Hammer. 2000. Effectiveness of earthen ramps in reducing big game highway mortality in Utah: Final Report. Utah Cooperative Fish and Wildlife Research Unit Report Series 2000 (1): 1-29. http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Connectivity/Description_of_Wildlife_Escape_Measures.pdf
Replace one-way gates with escape ramps.	Adaptive Ungulates Very High Openness Fauna	N/A	Bissonette, J.A. and M. Hammer. 2000. Effectiveness of earthen ramps in reducing big game highway mortality in Utah: Final Report. Utah Cooperative Fish and Wildlife Research Unit Report Series 2000 (1): 1-29.
Maintain fencing to prevent gaps in fence.	Adaptive Ungulates Very High Openness Fauna	N/A	

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Install Electromat at gaps in fencing, such as highway on/off ramps, driveways.	Adaptive Ungulates Very High Openness Fauna	N/A	http://www.electrobraid.com/wildlife/highway_fence.html Dodd, N. and J. Wise. The Nation's Most Advanced Game Crossing System. IMSA Journal 45(2); T.W. Seamans, Z.J. Patton, and K.C. VerCauteren. ElectroBraid Fencing for Use as a Deer Barrier. http://www.itre.ncsu.edu/cte/icoet
Construct crosswalk at controlled gap in fencing to allow animals to cross at-grade.	Adaptive Ungulates Very High Openness Fauna	N/A	Gagnon, J.W., N.L. Dodd, S.C. Sprague, K. Ogren, and R.E. Schwuinsburg. 2010. Preacher Canyon Fence and Crosswalk Enhancement Project Evaluation. Report No. JPA 04-088. Arizona Department of Transportation, Phoeniz, AZ. http://www.azgfd.gov/w_c/StateRoute_260_Elk_Crosswalk.shtml
Install shoulder or median barriers with scuppers (at least 25cm high and 100cm wide) every 5th barrier to faciliate small animal passage through the barrier.	Moderate Mobility Small Fauna	N/A	Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Arrange shoulder or median barriers with intermittent gaps to faciliate wildlife passage at-grade.	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna		Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.
Replace concrete shoulder and median barriers with cable median barriers where it is desirable to facilitate at-grade wildlife passage [cable barriers are considered more permeable for all species guilds than box-beam barriers, though more research is needed].	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	N/A	Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.
Install double cattle-guards and convert existing flat-bar cattle guards with round bars at controlled gaps in wildlife fencing, e.g., driveways or county roads. [May not be effective for all species]	Adaptive Ungulates Very High Openness Fauna	N/A	Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006. Evaluation of wildlife crossing structures and fencing on US Highway 93, Evaro to Polson. Phase I: Preconstruction data collection and finalization of evaluation plan. Final report. Western Transportation Institute, College of Engineering, Montana State University.
Avoid gaps in wildlife fencing or walls.	ALL	N/A	

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Add or Adjust Structural Features			
Fix perched outlets to allow access into culvert.	Moderate Mobility Small Fauna	Class 1	
Add a gutter pipe for small mammals.	Moderate Mobility Small Fauna	Class 1	Foresman, K.R. 2004. The effects of highways on fragmentation of small mammal populations and modifications of crossing structures to mitigate such impacts. Final Report. FHWA/MT-04-005/8161.
Bore new dry culverts adjacent to innundated culverts to promote wildlife passage through drainages.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1	
Add bat boxes.	Aerial Fauna (bats)	Classes 3, 4, 5	
Install poles placed on bridge edges to help birds perceive the barrier and avoid colliding with vehicles.	Aerial Fauna	Animal-vehicle collision prevention mechanisms at roadway bridges bisecting flyways	FHWA. Keeping it Simple - Oklahoma. http://www.fhwa.dot.gov/environment/wildlifeprotection
Install aerial bridges across highways between poles to facilitate arboreal crossings.	Arboreal Fauna	Class 6	NCDOT flying squirrel platforms Rope bridges over roads

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	NOTES & REFERENCES
Decommission old roads through a structure and restore natural landscape features to convert to a wildlife crossing.	ALL	Class 3	

APPENDIX D.

STRUCTURE EVALUATIONS, MONITORING RESULTS AND RECOMMENDATIONS FOR IMPROVING PERMEABILITY FOR TERRESTRIAL WILDLIFE IN WASHINGTON STATE

Conducted by:

Julia Kintsch, ECO-resolutions, LLC

Dr. Patricia Cramer, Utah State University

For:

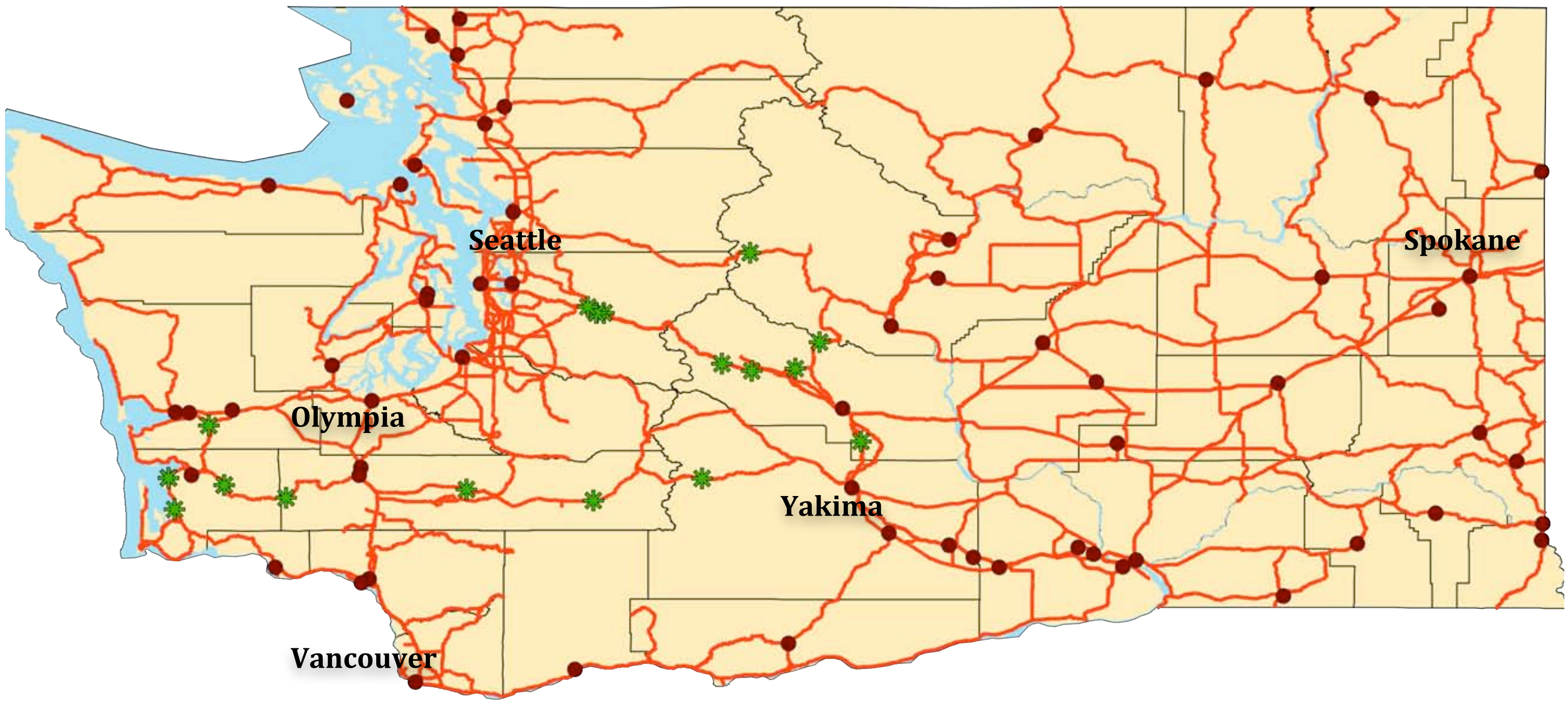
Washington State Department of Transportation

April 2011

Site assessments were conducted at seventeen highway structure locations (i.e., bridges or culverts) along eight state-maintained roadways between June 21 to 24, 2010 (Map 1). The purpose of these assessments was to test a system for evaluating existing structures with regards to their potential to pass different types of wildlife. The evaluation system is designed to help WSDO identify barriers to wildlife passage in existing transportation infrastructure and opportunities for retrofitting these structures so that they are more functional for passage of the diverse wildlife in Washington.

Following are the results of this evaluation and subsequent retrofit recommendations at all 17 of the assessed locations. These results are provided as examples of the evaluation system and how it can be use to determine preliminary recommendations for retrofitting or replacing bridges and culverts to enhance permeability for terrestrial wildlife. Each example includes descriptions of the roadway situation and general environs, the structure, and the surrounding habitat and terrain. These descriptions are followed with specific recommendations and guidance as to how the authors came to these recommendations.

Monitoring cameras were placed at 6 of these evaluation sites (2 cameras at each site) for 6 months. Two additional sites near North Bend were removed from the monitoring study due to vandalism. Summaries of the monitoring results are presented for each site after the site evaluation. The monitoring summaries provide



Map 1. Location of culverts and bridges evaluated in this study for their ability to pass terrestrial wildlife (green stars). Major cities are denoted by dark circles.

an overview of the photographic data including the number of deer and elk at the site, if the animals used the structure or were repelled (animals that looked into the structure's passage and turned away), seasonal use of the structure by deer, and tallies of all species detected at the site. For each site six sample pictures of the camera data are displayed to demonstrate wildlife activity at the site. These datasets can help WSDOT determine how different species will use certain structures more readily than others. The summaries also help support and clarify conclusions drawn during the site evaluations and refine the recommendations provided to better adapt the crossings for wildlife passage.

Monitoring at these sites entailed the placement of motion-triggered trail cameras inside metal utility boxes. Cameras were placed at either end of the outside edges of the structure. The cameras were locked to bicycle cables which were embedded in 60 to 120 pounds of concrete on the inside bottom of the utility box. Cameras were checked every two weeks. Camera visits entailed changing batteries and exchanging flash cards with photographic data. Data was transferred to Dr. Cramer via exchanges of thumb drives. Data was analyzed and entered into Excel spreadsheets for final tallies.

Of particular note during this study was elk use of two large bridged structures under I-90. Research throughout the western United States has documented the species' reluctance to pass through confined spaces such as culverts or small, restricted bridges. However, photographic evidence compiled through this research project shows elk movements under bridges that were wide, but less than 10 feet (3 m) high. This new insight may help WSDOT and other agencies to better design cost-effective bridged structures suitable for elk, and realize the potential for elk passage at existing bridges.

A very interesting site included in this study is a pair of corrugated steel culverts under I-90 near North Bend, Washington (Milepost (MP) 29). These culverts are located in a thickly vegetated area. Judging from the characteristics of the structures and the fact the small stream through this crossing was placed underground for half the crossing, and is above ground on the north side, it appears these culverts were designed specifically for wildlife passage. If wildlife were not considered, the stream could have been shunted underground for the entire length of the passage. This culvert appears to be among the most successful black bear crossings in the western U.S., as demonstrated by 31 black bear observations during 5 months of study. In comparison, at over 40 camera sites in two states combined (Montana and Utah) there have been less than 12 successful black bear crossings tallied over the course of two years. This passage is very successful particularly for black bear, whereas only three bobcats approached and crossed through the structure, and 7 of 19 approaches by coyotes were repelled. Our camera technician on several occasions could smell the bear presence in the culverts when she came to check the cameras. This may explain the low diversity of species using it. It may also support the idea that in an area of high species diversity, multiple crossings may be necessary for prey, predator and even competitor species.

Location Name: Mosquito Creek

Location ID: 101_76.5_01
Route: 101 ***Milepost***: 76.5

Roadway & Site Description
This segment of Route 101 is a two-lane road that runs north-south along the southwestern coast of Washington, traversing several drainages that feed into the coastal waters. The surrounding habitat is largely forested in nature.

Structure Description
Type: Concrete box culvert
Structure Functional Class: Class 2 (medium underpass)
Dimensions: 7' high x 15'9" span x 138' long

Mosquito Creek is a small, seasonal creek. Water flow through the structure at the time of the survey was shallow. The stream channel is naturally entrenched upstream and downstream of the roadway with thick bushes and trees to the edges of the banks. While the concrete box culvert at this location is large enough to allow for a relatively natural water flow through the structure, the stream channel is not maintained through the structure and the flow instead flattens out across the width of culvert. During low flows, muddy/gravely pathways are present through the structure, although these likely become obliterated during higher flow periods.

There is no fencing associated with either side of the structure. Guardrail is present above the structure for the span of the structure, but not along the rest of the roadway segment. There is no apparent human activity at this structure.

Wildlife
Raccoon, muskrat and small rodent tracks were observed in the muddy banks inside the structure. Raccoon tracks were also observed outside of the structure.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for Low Mobility Small Fauna, Moderate Mobility Small Fauna, and Adaptive High Mobility Fauna, meaning that the field evaluators concluded that animals from each of these guilds could successful pass through this structure as is or with small modifications. The structure received a 'C' rank for High Openness High Mobility Carnivores and Adaptive Ungulates, indicating that the structure could be modified to be made functional for species of these Movement Guilds. The structure received an 'F' rank for Very High Openness Fauna, meaning that the structure cannot be retrofit to accommodate these species.

Recommendations

Overall, the evaluators determined that the culvert, as is, is not quite high enough to be a highly functional passageway, although it can still be used by some individuals of the more reluctant species, such as black-tailed deer. The addition of wildlife fencing tied into the structure would enhance usage by High Openness High Mobility Carnivores, such as bear or mountain lion, and Adaptive Ungulates, such as black-tailed deer. Greater functionality for bucks as well as does and fawns, and for Very High Openness Fauna such as elk would require replacement with a larger structure. Maintaining built up dirt banks along one or both of the inside edges of the culvert can also help to provide dry pathways for smaller animals during higher water flows.

Figure 1. Rte 101 looking south

Figure 2. View from outlet

Figure 3. Muddy pathway through culvert

Figure 4. Looking towards outlet

Monitoring Results

US 101 Mosquito Creek Culvert

This concrete box culvert is under US 101 south of Aberdeen, Washington. At times of low flow, there is a muddy path to the side of the creek. There is no wildlife fencing at this site. The area is heavily vegetated and forested. WSDOT estimates for Average Daily Traffic approximates 5,000 vehicles. On June 9, 2010, two cameras were placed at the culvert entrances, both positioned facing inward.

In 138 days of monitoring, this culvert was most heavily used by black-tailed deer, specifically does and fawns. Of the 71 deer observations at the site, only two were of black-tailed deer bucks, the remainder was of does and fawns, probably the same family of three moving to either side of the road. One buck repelled from the structure, the second followed a doe and fawns through the structure, see photos below. Deer use peaked in June and early July, see Figure 5. Deer data is presented in Table 1.

Table 1. Black-tailed deer observation data tabulated for US 101 Mosquito Creek box culvert.

Camera Days Analyzed	Deer Photo-obs. at Site	Deer Photo-obs. per Day	Number of Successful Crossings through structure	Successful Deer crossings per day	Success Rate (%)	Rate of Repellency (%)	Parallel Rate (%)
138	71	0.51	60	0.43	84.5	5.6	9.9

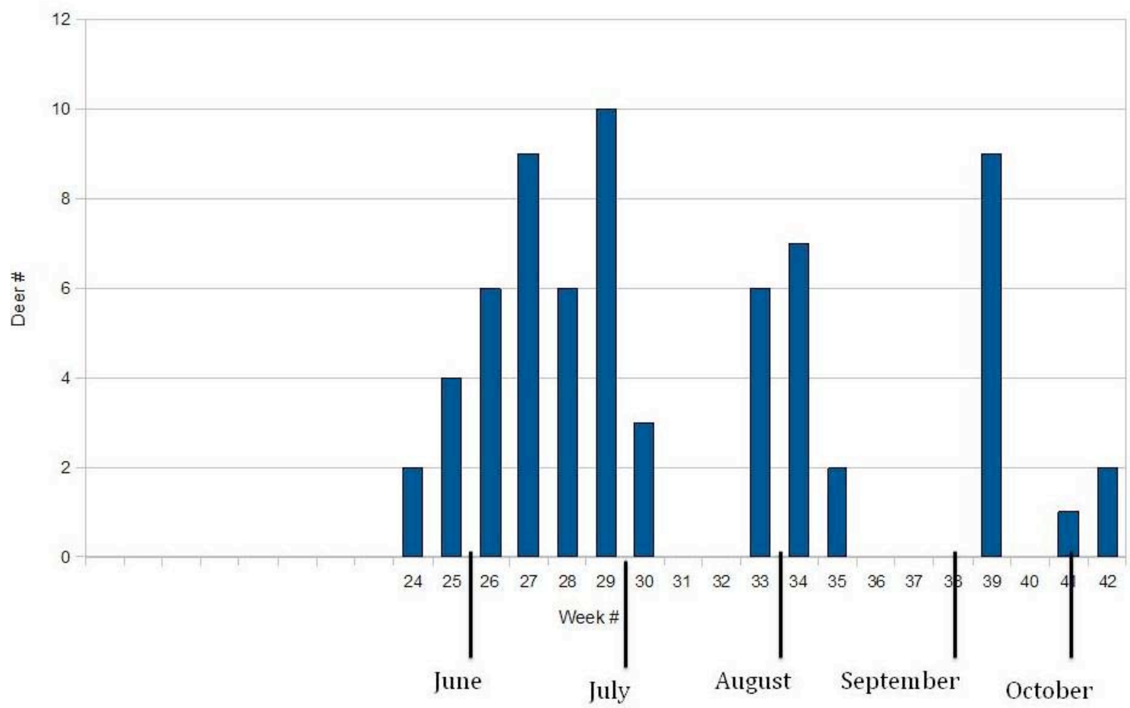


Figure 5. Black-tailed deer passes through culvert per week at US 101 Mosquito Creek culvert over the weeks of monitoring in 2010.

One elk was photographed grazing at the entrance to the culvert. It did not enter the structure, (see photos below). The remaining species observed are presented in Table 2.

Table 2. Species and number of detections at the US 101 Mosquito Creek culvert.

Species

Mammals	Birds
Black-tailed deer - 71	Crow - 3
Raccoon - 18 events, 36 individuals	Raven - 1
Cat - 18	
Humans - 2	

Figure 6. Black-tailed deer doe and fawns at US 101 Mosquito Creek culvert, they just passed through the culvert.

Figure 7. Black-tailed deer buck repelling from US 101 Mosquito Creek culvert.

Figure 8. Black-tailed deer fawns looking up at US 101 from Mosquito Creek.

Figure 9. Only buck photographed using US 101 Mosquito Creek culvert. Following doe and fawns.

Figure 10. Raven at Mosquito Creek culvert entrance under US 101. There is no evidence the raven went into the culvert.

Figure 11. The only elk photographed at US 101 Mosquito Creek culvert. It did not enter the culvert.

Location Name: Middle Fork Nemah River

Location ID: 101_38.8_02
Route**:* 101 ***Milepost: 33.8

Roadway & Site Description

This segment of Route 101 is a two-lane road north-south along the southwestern coast of Washington, traversing several drainages that feed into the coastal waters. Traffic levels at the time of the evaluation were low, but regular. A 10-minute traffic count resulted in an estimated daily average of 5,000 vehicles, which could inhibit some wildlife from attempting to cross at-grade. The surrounding habitat is largely forested in nature.

Structure Description

Type: Wooden multi-span
Structure Functional Class: Class 3 (large underpass)
Dimensions: 8'5" high x 61'4" span x 29' long

This structure is a multi-span bridge underpass with wooden supports. The center span bridges the main portion of the stream while the two outside spans bridge the stream banks although water may pass through these sections during periods of high flows. The full height of the structure is realized only beneath the center span, whereas the outside chambers have higher stream banks/sediment, resulting in a significantly shorter functional height for animals passing through these sections. Water flow through the structure was approximately 3-10' deep at the time of the evaluation

There is no fencing associated with the structure. Guardrail is present above the structure for the span of the structure. There is no apparent human activity at this site.

Wildlife

A roadside ditch along the east side of the road containing standing water and vegetation was found to have a Northwestern salamander egg mass, though no larvae remained in the eggs. A shrew was also observed at the inlet side of the structure.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for each of the target Species Movement Guilds, meaning that the field evaluators determined that animals from each of these guilds could successful pass through this structure as is or with small modifications.

Other Considerations

The following considerations warrant additional follow-up:

- What is the land-ownership in this area? Are there any concerns with private lands development near the structure?

Recommendations

Despite the 'A' rankings for all of the Species Movement Guilds, several retrofit recommendations are advised at this site:

- Remove the center supports to create a more open single-span structure (may not be possible without replacing the entire structure);
- Construct dry, natural dirt pathways on both sides of the stream that remain dry during seasonal high water;
- Minimize or cover riprap on side-slopes with dirt to create a dry, smooth pathway;
- Maintain the structure height for the full length of the span (so that the distance from the ground level to the ceiling of the structure is high enough to allow the passage by ungulate species and other larger mammals);
- Install wildlife fencing for larger mammals and salamander walls to guide animals towards the structure.

Figure 12. Rte 101 looking North

Figure 13. Rte 101 looking South

Figure 14. Bridge at Location 101_38.8_02

Figure 15. Stream flow through the center span portion of the bridge

Figure 16. Stream bank under outside span

Figure 17. View from structure to east (inlet side)

Location Name: Bone River

Location ID: 101_45.3_03

Route**:* 101 ***Milepost: 45.3

<u>Roadway & Site Description</u>

This segment of Route 101 is a two-lane road north-south along the southwestern coast of Washington, traversing several drainages that feed into the coastal waters. The surrounding habitat is largely coastal marsh and forest.

<u>Structure Description</u>

Type: Wooden bridge underpass
Structure Functional Class: Class 4 (extensive bridge)
Dimensions: 100' span x 25' long

This structure is an extensive wooden bridge traversing a tidal river. The river is broad and deep, as the roadway is parallel to Willapa Bay. The river is highly influenced by the tides. While the river is largely confined within its channel, at high tide the adjacent riverbanks are flooded, eliminating any dry pathways for wildlife through the structure. The north side of the structure is reinforced with concrete sand bags, eliminating the natural banks through the structure.

There is no fencing associated with the structure. Guardrail is present above the structure for the span of the structure. There are no immediate signs of human activity at this structure, although camera monitoring did capture some human activity.

<u>Wildlife</u>

No wildlife signs were observed at the time of the evaluation, but most signs are likely obliterated during daily high tide events, and camera monitoring revealed a variety of wildlife activity at this location.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for Moderate Mobility Small Fauna, meaning that the field evaluators determined that animals from each of these guilds could successful pass through this structure as is or with small modifications. The structure received a 'C' rank for all other species guilds, indicating that the structure could be modified to be made functional for species of these Movement Guilds. Given that this location is a tidal system, it was not evaluated for Low Mobility Small Fauna, such as frogs and salamanders.

<u>**Recommendations**</u>

Given the tidal nature of this system, a structure at this location is not useable by wildlife during the daily high tides. The following recommendations can help make the structure more functional during low and high tides

- Expand the span to include more of the riverbanks, including a minimal dry or semi-dry pathway during high tides.
- Install wildlife fencing for larger mammals and salamander walls to guide animals towards the structure.

Figure 18. Inlet side, looking west.

Figure 19. Bank on south side of structure during low tide.

Figure 20. Roadway looking south

Figure 21. Structure looking southeast

Figure 22. Bank under structure on north side

Monitoring Results

US 101 Bone River Bridge
The highly tidal Bone River runs under this bridge. The river is wide, over 50 meters across. The northern end of the bridge has a dry land passage on the 2 to 1 slope under the bridge, while the southern end has a steeper, rip rap slope that is difficult to use for terrestrial passage. Cameras from both ends of the bridge documented high tides that could make terrestrial passage difficult. Average Daily Traffic approximates 2,700 vehicles. There is no wildlife fencing at this site. The area is heavily vegetated and forested, with the west side gradating to tidal marsh. On April 13, 2010, two cameras were placed at this high arch bridge, along US 101, south of South Bend, Washington. The cameras were positioned on dry ground pointed toward the underside of each end of the bridge.

In 197 days of monitoring, the bridged area was rarely used by deer. There were 16 deer observations at the north end of the bridge for an average of 0.08 deer observations per day. All deer photographed were black-tailed deer does and fawns. All deer were photographed between May 12 and July 30, 2010. In six of the 11 events when deer were photographed, the deer could be seen moving under the bridge, solely on the north end of the structure. This amounts to 10 deer out of 16 using the structure, for a success rate of 62.5%. The rest of the movements were parallel. Eight deer events were during the day, 2 occurred at night, and one at dawn.

No other ungulates were photographed. Human use was fairly high at this structure, with 37 events were people came by to prepare the area for construction, apply pesticides, collect plants, fish, hike, clam, and ride in boats up and down the river. One pair of travelers spent the night camping in front of the south camera. Meso-mammals were fairly common at this site, with more raccoon and coyote observations occurring in front of these cameras than any other sites in the study.

Table 3. Species detected at the US 101 Bone River bridge culvert and the number of observations for that species.
Species
<u>Mammals</u>
Black-tailed deer - 16
Humans – 37
Raccoon 54 events - 68 individuals
Coyote - 14 events, 15 individuals
River Otter - 1
Rabbit - 1

Seasonal use of the area by all species was tallied. Wildlife detection rates were fairly constant per month over time (Table 4).

Table 4. Monthly tallies for number of wildlife events recorded by cameras at Bone Creek Bridge, US 101.

Month	Number of wildlife events recorded	Month	Number of wildlife events recorded
April	17	August	5
May	11	September	13
June	11	October	11 (all raccoon events)
July	12	-	-

Figure 23. Black-tailed deer doe and yearling using north end of Bone River Bridge, US 101.

Figure 24. Black-tailed deer doe coming through bridge over Bone River, US 101.

Figure 25. Coyote looking to the west toward Willapa Bay from south end of Bone River Bridge, US 101. Coyotes attempted to move under the bridge at this site, but never appeared to succeed, always coming back.

Figure 26. Only river otter photographed in study, using area near southern base of Bone River Bridge, US 101.

Figure 27. Flooding of uplands along Bone River, south end of Bridge, US 101.

Figure 28. Curious raccoon at south end of Bone River Bridge, US 101.

Location Name: Willapa River

Location ID: 6_6.8_04
Route: 6 ***Milepost***: 6.8

<u>Roadway & Site Description</u>
This segment of State Highway 6 is an east-west running, undivided two-lane road. A bike path runs parallel to the roadway along the north side along an old railroad grade. The structure spans the Willapa River as it is bisected by the highway. The surrounding landscape is largely agricultural with some residences.

<u>Structure Description</u>
Type: Concrete span bridge
Structure Functional Class: Class 4 (extensive bridge)
Dimensions: 25' high x 100' span x 28' long

This structure is large multi-span bridge spanning the river and adjacent river banks. The height of the structure over the grassy river banks is approximately 15', leaving sufficient room for even large animals to pass beneath the structure.

There is no fencing associated with the structure. Guardrail is present above the structure for the length of the structure. There were no evident signs of human activity at this structure, however camera monitoring at this location captured dozens of human events throughout the monitoring period.

<u>Wildlife</u>
A wildlife trail crosses under the structure and deer tracks were observed at the time of the evaluation.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds This location received an 'A' rank for each of the target Species Movement Guilds, meaning that the field evaluators determined that animals from each of these guilds could successful pass through this structure as is or with small modifications.

<u>Recommendations</u>
Wildlife appeared to be using the structure, a conclusion that was verified through the camera monitoring (see monitoring results below). Wildlife fencing could be constructed to guide animals to the structure; however, it is uncertain whether such a measure is necessary. We recommend first assessing animal-vehicle collision rates at this location and communicating with adjacent landowners to determine whether animals are crossing at-grade along this segment of roadway.

Figure 29. West looking towards bike path bridge

Figure 30. Inlet side

Figure 31. Span over riverbank

Figure 32. Looking upstream

Figure 33. Primary section of span where river flows

Monitoring Results

SR 6 Willapa River Bridge

This bridge straddles the Willapa River several miles southeast of Raymond, Washington. The road is high above the river and surrounding upland, allowing for ample terrestrial movement on both banks under the bridge. Grass is the dominant vegetation at this bridge. Homes are within 50 meters at both the east and west sides of the road and north and south of the river, but there are also agricultural fields that are adjacent to the bridge on other corners. There is no wildlife exclusion fencing at this site. WSDOT estimates of Average Daily Traffic volume varies from 1,700 to 2,700 vehicles.

On April 14, 2010, two cameras were placed at each base of the bridge, on each side of the river. In 196 days of monitoring, the north camera was in operation 173 days and the south camera 148 days. From June 24 through July 14 no cameras were in operation. There were a total of 82 deer observations. The average deer observations per day was 0.42. Of the total deer, there were seven males, 56 females, and 19 young. Due to the dense grass vegetation and camera placement, actual repels and parallels could not be calculated. The 82 deer observations occurred in 51 events. The majority of these events (36) occurred on the north (west) end of the bridge. The majority of the events (36, 70.6%) occurred during the day. Deer use peaked in late June and early July, but otherwise was consistent throughout the study period. See Figure 34 below.

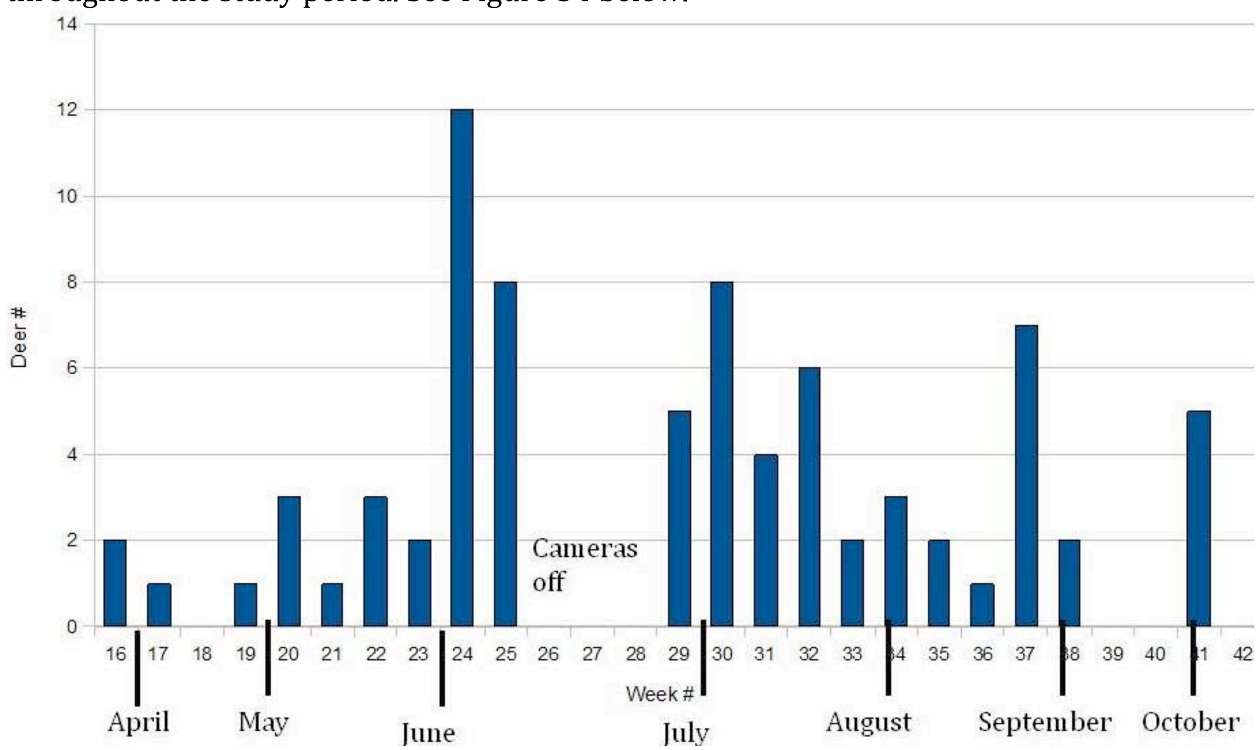


Figure 34. Black-tailed deer observations per week at SR 6 Willapa River Bridge over the weeks of monitoring in 2010.

Other species of wildlife were present at this bridge. This was the crossing for opossum, with 90 observations of this species, many of which were of different sizes, indicating more than just one or two animals. A single cat was responsible for the 73 cat events. It would sit in front of the camera, apparently watching for wildlife. One night an opossum did come and run directly in front of the cat, see picture below. Human use was persistent, with 43 events of people coming to the area to swim, bring tubes to float the river, fish, hike, walk dogs, and canoe. The majority of human events occurred at the north (west) end of the structure.

Table 5. Species observations at the SR 6 Willapa River Bridge.

Species

Mammals
Black-tailed deer - 82
Opossum - 90
Raccoon - 28 events, 27 individuals
Cat - 73
Skunk - 5
Coyote - 1
Dogs (only) - 12
Humans (only) - 41
Humans with dogs - 2

Birds
Robins - 1 event, 2 individuals

Wildlife events were fairly consistent across the months. After removing all events involving humans, dogs and cats, the pure wildlife events (including deer) were tallied for each month (Table 6). June was the month with the greatest wildlife activity.

Table 6. Monthly tallies for number of wildlife events recorded by cameras at Willapa River Bridge, SR 6.

Month	Number of wildlife events recorded	Month	Number of wildlife events recorded
April	18	August	26
May	15	September	25
June	41	October	7
July	21		

Figure 35. Black-tailed deer doe entering area under north side of bridge.

Figure 36. Two black -tailed deer does using area under south side of bridge.

Figure 37. Opossum using area under north side of bridge. Vegetation near opossum is attached to its tail.

Figure 38. Black-tailed deer doe and fawn in area where grass has been cut, north end of SR 6 Willapa River Bridge.

Figure 39. Black-tailed deer entering south end of bridge. Note long grass.

Figure 40. Cat and opossum under north side of bridge. Cat and opossum ran away in opposite directions.

Location Name: Rock Creek

Location ID: 6_26_05
Route: 6 ***Milepost***: 26

Roadway & Site Description
This segment of State Highway 6 is an east-west running, undivided two-lane road. A bike path runs parallel to the roadway along the north side along an old railroad grade. Rock Creek runs through the structure, which is surrounded by forest cover to both the north and south.

Structure Description
Type: Concrete span bridge
Structure Functional Class: Class 3 (large underpass)
Dimensions: 16'7" high x 106' span x 24' long

This structure is an old multi-span bridge underpass (plaque indicated it was constructed in 1924) with concrete support posts, which provide a more open feel through the structure. The center span bridges the main portion of Rock Creek – which was approximately 3-10' deep at the time of the assessment – while the two outside spans bridge riprap side slopes. The riprap is mostly larger sized (i.e., larger than a volleyball), although on the east side of the creek there is a narrow dry pathway composed of smaller riprap and dirt.

There is no fencing associated with the structure on the inlet (south) side. Limited 4-strand barbed wire fencing extends to the west for approximately 100' on the north side of the structure. This fencing is in poor condition with multiple holes and areas where the vegetation is pulling down the fence. Guardrail is present above the structure for the length of the structure. There is little evidence of human activity at this structure, although a few footprints were observed.

Wildlife
Deer, raccoon, and small rodent tracks were observed by the structure, and ermine scat was found beneath the structure.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received 'C' ranks for Low Mobility Small Fauna, Adaptive Ungulates, and Very High Openness Fauna, meaning that structure could be retrofitted to better accommodate species of these guilds. All other species guilds received an 'A' rank. In general, the field evaluators determined that the structure is large and open enough to accommodate each of the target Species Guilds, but the riprap decreases the functionality of the structure for several Species Guilds.

Recommendations

Following are the recommended retrofits at this site:

- Alter or cover riprap on side slopes to provide a dirt pathway through the riprap on either side of the creek; Maintain natural stream banks to the extent possible.
- Maintain native vegetation growth at the structure entrances and avoid the use of herbicides in these areas.
- Install wildlife fencing for larger mammals and small mammals to guide animals towards the structure.

Figure 41. Highway 6 looking east

Figure 42. Highway 6 looking west

Figure 43. Bridge and riprap side slopes

Figure 44. Main span

Figure 45. Bridge and adjacent forest

Figure 46. 4-strand barbed wire fencing on northwest side of structure

Location Name: Unnamed Tributary, Tilton River

Location ID: 508_24_06
Route: 508 ***Milepost***: 24

<u>Roadway & Site Description</u>
Highway 508 is an east-west running two-lane highway through in southwestern Washington. This segment of the road crosses through forested, mountainous terrain.

<u>Structure Description</u>
Type: Wooden bridge
Structure Functional Class: Class 2 (medium underpass)
Dimensions: 3'6" high x 24' span x 20' long

This structure is a small bridge underpass with straight, wooden abutments that spans a small stream, less than 3' deep at the time of the assessment. The structure spans only the stream itself and does not include any dry bank area beneath the bridge

There is no fencing associated with the structure. Guardrail is present above the structure for the length of the structure. There is no apparent human activity at this structure.

<u>Wildlife</u>
No wildlife signs were observed at this structure.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. Because of the lack of a dry terrestrial pathway through the structure, this location received 'C' ranks for Low Mobility Small Fauna, Moderate Mobility Small Fauna and Adaptive High Mobility Fauna. The structure received 'F' ranks for High Openness High Mobility Carnivore, Adaptive Ungulates, and Very High Openness Fauna because it is too small to accommodate species in these Movement Guilds, and cannot be retrofit to accommodate them. A new structure would be required at this location to provide a safe passage for members of these Guilds.

<u>Recommendations</u>

Following are the recommended retrofits at this site:

- Improve for small mammals by providing a dry pathway on one side of the stream either by constructing an artificial bank through the structure using small-diameter riprap and dirt, or by installing a small mammal shelf through the structure.

Following are the recommendations for replacing the structure to accommodate larger wildlife, such as deer, coyote and elk:

- Elevate the roadway to accommodate a higher structure;
- Construct a wider structure that spans the banks on either side of the stream to provide a dry pathway. Or create a double structure that accommodates the stream on one side, and the terrestrial passage an overflow in the other.
- Install wildlife fencing for larger mammals and small mammals to guide animals towards the structure.

Figure 47. Route 508 looking west

Figure 48. Outlet side

Figure 49. Looking downstream from outlet

Figure 50. Inlet side

Location Name: Cowlitz River

Location ID: 12_112.8_07

Route: 12 ***Milepost***: 122.8

Roadway & Site Description

This segment of State Highway 12 is an east-west running, undivided two-lane road. A small county road intersects the highway immediately to the west of the structure. The surrounding landscape is largely agricultural, with a narrow strip of riparian forest lining the river. A wide clear zone adjacent to the road pavement is maintained on both sides of the road.

Structure Description

Type: Steel and concrete span bridge

Structure Functional Class: Class 4 (extensive bridge)

Dimensions: 22' high x 200' span x 33' long

This structure is an extensive bridge spanning a broad river and adjacent banks, with multiple rows of concrete support posts along the length of the span. The bridge spans across the natural high bank slopes, such that there is a wide terrestrial area beneath the structure, even during periods of high flows. However, there is little vegetation cover beneath the structure itself. A dirt road extends from the highway to the structure entrance on the northwest side, for people to directly access the river.

There is no wildlife fencing associated with the structure, although the adjacent agricultural fields are fenced. There is a limited segment of guardrail associated with the structure. Human activity is apparent at the structure, and both human and dog tracks were observed.

Wildlife

Deer tracks were observed under the structure, and both deer and elk tracks were observed in the vicinity of the structure. Elk tracks were also found along the roadside. A game trail was found leading from the riparian zone along the fenced-off agricultural fields on the southwest side up to the guardrail.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for each of the target Species Movement Guilds, meaning that the field evaluators determined that animals from each of these guilds could successful pass through this structure as is or with small modifications.

Recommendations

Following are the recommended retrofits at this site:

- Install wildlife fencing for larger mammals and small mammals to guide animals towards the structure.
- Minimize human activity at the structure; provide river access further up- or downstream from the structure itself.

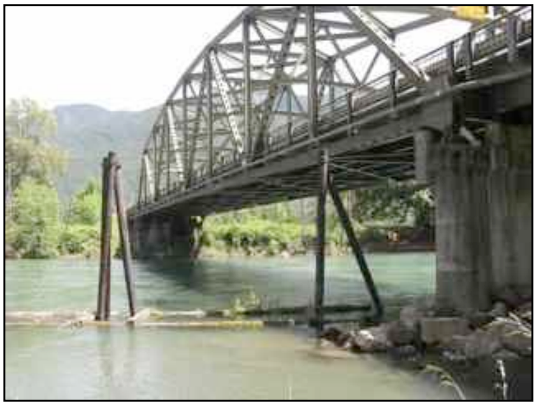


Figure 51. Inlet side

Figure 52. Terrestrial area beneath bridge

Figure 53. Outlet side

Figure 54. Looking towards inlet

Figure 55. Game trail from riparian Zone and fenced fields to guardrail

Figure 56. Roadway

Location Name: Indian Creek

Location ID: 12_159_08

Route: 12 ***Milepost***: 159

<u>Roadway & Site Description</u>

This segment of State Highway 12 is an east-west running, undivided two-lane road. The surrounding landscape is forested and in National Forest ownership. A horse ranch operates on the north side of the highway.

<u>Structure Description</u>

Type: Steel and concrete span bridge

Structure Functional Class: Class 4 (extensive bridge)

Dimensions: 8' high* x 150' span x 32' long

> **Note*: this is the functional height of the terrestrial pathway under the bridge, not the height from the river to the bridge.

This structure is an extensive bridge spanning a mountainous river drainage. The bridge spans the river as well as the adjacent high banks. It is supported by concrete pillars on both sides of the river and riprap reinforcement at the abutments. A defined dirt pathway is evident crossing through the structure, and appears to be used by horseback riders and wildlife alike. There is no vegetation cover beneath the structure itself.

There is no wildlife fencing associated with the structure, although the adjacent agricultural fields are fenced. Guardrail is present above the structure for the length of the structure. Human activity at the structure appears limited to occasional use by horseback riders. An interview with the horse ranch operators could confirm the level of human use.

<u>Wildlife</u>

A game trail passes through the structure and a number of both deer and elk tracks were observed under the structure and in the adjacent habitat, as well as leading up to the roadsides. Small rodent scat was also found in the structure. Heavy elk droppings were observed in areas leading to the structure.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received 'A' ranks for Moderate Mobility Small Fauna, Adaptive High Mobility Fauna, and High Openness High Mobility Carnivores. The structure received 'C' ranks for Adaptive Ungulates and Very High Openness Fauna because the lack of a dry pathway on the west side of the river makes it impassable for species in these groups through that portion of the structure. The structure received a 'F' for Low Mobility Small Fauna because of the lack of natural riparian stream banks through the structure.

Recommendations

Following are the recommended retrofits at this site:

- Construct natural substrate pathways along the water's edge for riparian species moving along that edge.
- Install wildlife fencing for larger mammals and small mammals to guide animals towards the structure and prevent at-grade crossings.
- Minimize human/horse activity at the structure; ensure appropriate access and controls for the horse ranch to ensure that if new wildlife fencing is installed it will not be in conflict with their needs.
- Maintain vegetation cover at structure entrances.

Figure 57. Roadway looking east

Figure 58. Inlet side

Figure 59. Steep bank on west side

Figure 60. Dry pathway on east side

Figure 61. View towards inlet

Location Name: McPherson Creek

Location ID: 823_13.8_09
Route: 821 ***Milepost***: 13.8

Roadway & Site Description
State Highway 823 is a north-south running, undivided two-lane highway. The surrounding landscape is sagebrush. There is no development along this segment of roadway. Average daily traffic is predicted to be less than 2,000 vehicles.

Structure Description
Type: Concrete box culvert
Structure Functional Class: Class 2 (medium underpass)
Dimensions: 6' high x 5' span x 165' long

This structure is a box culvert at the base of an approximately 15-foot high fill slope. The structure is positioned at an angle to the roadway, and appears as a long, narrow tunnel. The culvert floor is concrete. The drainage on the inlet side is wide and open, whereas on the outlet side it is narrow and steep. Woody debris and tumbleweeds have built up at the structure outlet, partially blocking the entrance It appears the culvert is placed for an occasional flash flood.

Four-foot high barbed wire fencing is present on the inlet (east) side of the structure. The fence does runs across the top of the fill slope and extends approximately 100 feet in either direction. There is no wildlife fencing associated with the outlet (west) side of the structure. There is no evidence of human activity at this location.

Wildlife
Deer tracks were observed in the drainage on the inlet (east) side of the structure. The tracks do not approach the structure, but instead lead up the side of the fill slope, suggesting that they are crossing at-grade.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for Moderate Mobility Small Fauna and a 'C' rank for Adaptive High Mobility Fauna. The structure received 'F' ranks for Low Mobility Small Fauna, High Openness High Mobility Carnivores, Adaptive Ungulates and Very High Openness Fauna, meaning that it cannot be retrofit to accommodate species in these Movement Guilds.

Recommendations

The existing structure is insufficient for most Species Movement Guilds and would have to be replaced with a larger box culvert, arch or bridge structure to provide a suitable passage for animals in these groups. Barring replacement, the structure could be made more functional for Moderate Mobility Small Fauna and Adaptive High Mobility Fauna by the following measures:

- Clear debris from the outlet and maintain on a regular basis.
- Add baffles to the culver floor to retain a dirt floor through the length of the structure.

Figure 62. Box culvert at base of fill slope

Figure 63. Long, narrow tunnel effect

Figure 64. Looking up the drainage from inlet

Figure 65. Debris at culvert outlet

Figure 66. Roadway looking north

Location Name: Teanaway River Bridge

Location ID: 970_6.3_10

Route**:* 970 ***Milepost: 6.3

<u>Roadway & Site Description</u>

SR 970 is an east-west running, undivided two-lane highway. The surrounding landscape is a mix of agricultural fields and forest, with riparian habitat maintained along the river corridor.

<u>Structure Description</u>

Type: Concrete bridge

Structure Functional Class: Class 4 (extensive bridge)

Dimensions: 17' high x 300' span x 43' long

This structure is a concrete bridge spanning a large river. The bridge has vertical support walls at intervals along its span. At either end of the structure the walls are further reinforced with riprap slopes. The riprap slopes occupy much of the terrestrial area beneath the bridge, particularly on the east side, where the riprap extends for approximately 50 feet beyond the structure. The riprap is less continuous on the west side, although there is no defined terrestrial pathway through the structure.

Four-foot high four-strand barbed wire fencing is present on both sides of the structure, extending for approximately 1 mile in either direction. There is also extensive guardrail present on both sides of the roadway. No signs of human activity were observed at this location.

<u>Wildlife</u>

Despite the lack of a well-defined pathway, deer tracks were observed crossing through the structure on the west side of the river along the flattest, least rocky section of the support slope.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for Moderate Mobility Small Fauna, Adaptive High Mobility Fauna and High Openness High Mobility Carnivores, meaning that the field evaluators concluded that animals from each of these guilds could successful pass through this structure as is or with small modifications. The structure received a 'C' rank for Adaptive Ungulates and Very High Openness Fauna, indicating that the structure could be modified to be made functional for species of these Movement Guilds. The structure received a 'C' rank for Low Mobility Small Fauna, meaning the area under the bridge can be retrofit to accommodate these species.

Recommendations
The following measures are recommended to improve the functionality of this structure.

- Create dirt pathways through the riprap on both sides of the river.
- Revegetate the stream banks through the structure to accommodate Low Mobility Small Fauna and other riparian-dependent wildlife.
- Replace the barbed-wire fencing with 8'-foot high wildlife fencing to guide animals towards the structure and discourage at-grade crossings.

Figure 67. Roadway

Figure 68. Support wall

Figure 69. Side slope on west side of river

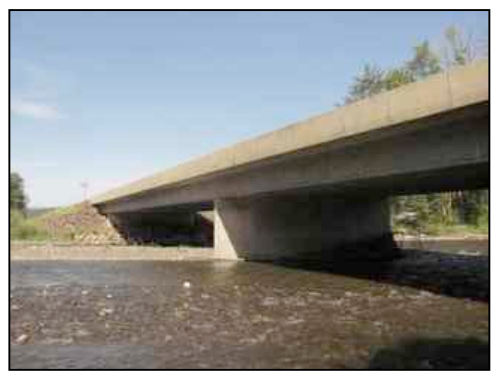


Figure 70. Bridge view from outlet

Figure 71. Riprap on east side of river outlet

Figure 72. View of drainage from

Location Name: Swauk Creek

Location ID: 970_159.7_11

Route*:* 97 ***Milepost***: 159.7

<u>Roadway & Site Description</u>

State Highway 970 is an east-west running, undivided two-lane highway. A 10-minute traffic count resulted in an estimated daily average of 8,000 vehicles, which could inhibit some wildlife from attempting to cross at-grade. This segment of roadway is located in a completely forested landscape.

<u>Structure Description</u>

Type: flat-bottomed metal pipe
Structure Functional Class: Class 2 (medium underpass)
Dimensions: 6' high x 9' span x 100' long

This structure is a flat-bottomed metal pipe with perennial stream flow situated in a low fill slope. The outlet is perched more than 0.5' feet above the channel and drops into a pool.

There is no fencing associated with the structure. Guardrail extends for approximately 200' in either direction on both sides of the roadway. No signs of human activity were observed at this location.

<u>Wildlife</u>

Deer tracks were observed in the drainage and appear to cross up and over the highway.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This structure received a 'F' rank for all species movement guilds and cannot be retrofit to accommodate terrestrial wildlife.

<u>Recommendations</u>

This structure must be replaced with a new structure to accommodate terrestrial wildlife passage for most Species Guilds at this location. A raised shelf could be placed along the length of the inside of the pipe and, with some effort, connected to the landscape at either end of the pipe to facilitate passage for smaller animals.

Figure 73. Riparian forest and culvert meadow at outlet

Figure 74. Flat-bottomed pipe

Figure 75. Roadway and adjacent forest

Figure 76. Inlet

Location Name: Mill Creek

Location ID: 2_70.2_12
Route: 2 ***Milepost***: 70.2

<u>Roadway & Site Description</u>
This segment of the east-west running state Highway 2 is a divided four-lane highway through the forested Cascade Mountains.

<u>Structure Description</u>
Type: Arch culvert
Structure Functional Class: Class 3 (large underpass)
Dimensions: 12' high x 36' span x 140' long*

> **Note both the north and south structures have approximately the same dimensions, although the south structure was not directly measured because of the lack of access due to the steep riprap slopes.*

There are two structures at this location; one under the eastbound lanes and another under the west bound lanes. Both structures are large arch culverts with perennial water flow through the structure. The structures are separated by wide (~200') vegetated median. The stream comes in from the south, where it is bisected by the highway, and meanders through the heavily-vegetated median, such that the north structure is offset from the southern one by about 1/10-mile. The north structure is situated in a low fill slope while the south structure is situated at the base of a somewhat higher and significantly longer fill slope.

Extensive riprap is associated with both structures as well as the stream banks through the median. At the north structure, riprap lines the stream banks (~30' wide) and adjacent fill slopes on both the outlet and median (inlet) sides of the structure. At the south structure, the extensive fill slope is reinforced with rip rap along its entire length.

Boulders have been placed inside of the structures to simulate a more natural flow. The culvert is completely occupied by the stream and, while the stream is not deep (less than 3' at the time of the evaluation), it is unlikely that even larger mammals would cross through these culverts.

There is no fencing associated with the structure. Guardrail extends throughout this segment on both sides of the roadway above both the north and south structures. While human use does not appear to occur regularly at this location, graffiti was found on the northern structure.

<u>Wildlife</u>
Deer and elk tracks were observed in the vicinity of the north structure on both the outlet and median sides. In one place, deer tracks were found crossing through the narrowest portion of the riprap to ascend the fill slope. Road kill was also found at

this location, most likely a squirrel or rabbit. Tracks were found along the roadway at both the north and south structures. Possible bighorn sheep tracks were observed along the road at this site.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This structure received a 'F' rank for all species movement guilds and cannot be retrofit to accommodate terrestrial wildlife. Notably, the structure has received awards for its ability to accommodate fish passage, highlighting the need to consider terrestrial as well as aquatic passage when designing and constructing structures.

Recommendations
While the structure must be replaced with a new structure to accommodate terrestrial wildlife passage, several improvements could be made to make the location more wildlife-friendly. These include:

- Minimize riprap on the slopes adjacent to the structure and/or provide 'escape pathways' for ungulates that are trapped on the roadway side of the riprap.
- Remove the slope netting, which may ensnare snakes and small animals.

Figure 77. North-side structure outlet

Figure 78. West bound lanes, looking east

Figure 79. View from north-side structure outlet

Figure 80. Riprap-lined stream bank and fill slope (north side structure inlet)

Figure 81. View from north- side structure across median to riprap fill slope along eastbound lanes

Figure 82. Riprap fill slope on south side (eastbound lanes)

Figure 83. From eastbound lanes looking across median towards north structure

Location Name: Cle Elum River Bridge (aka Bullfrog)

Location ID: 90_79_13
Route: I-90 ***Milepost***: 79

Roadway & Site Description
This segment of Interstate 90 is an east-west running, 4-lane divide highway (2 lanes in each direction). The surrounding landscape is largely forested.

Structure Description
Type: Concrete and Steel Bridges
Structure Functional Class: Class 4 (extensive bridge)
Dimensions: 12’ high x 150’ span x 30’ long*

> **Note both the north and south structures have approximately the same dimensions.*

There are two structures at this location; one under the eastbound lanes and another under the west bound lanes. Both structures are large concrete and steel bridges with concrete support walls. The Cle Elum River flows through the structure. The structures are parallel to one another and separated by 60’-wide vegetated median. There is minimal vegetation (some grasses) beneath the structures themselves.

The river occupies much of the span under the bridges, however there as a 50 feet wide dirt river bank on the west side of the river. On the east side, there is little terrestrial area – the concrete support wall is close to the waters edge and further supported by riprap. Visibility through both structures is very high.

There is no fencing associated with the structure. There appears to be occasional human activity at this location. The purpose of such visits is unclear, but may be recreational (e.g., river access).

Wildlife
Numerous deer tracks and scat were found under the structures on the west side of the river.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This structure received an ‘A’ rank for all species movement guilds, indicating that animals from each of the Movement Guilds could successful pass through this structure as is, although passage could be further enhanced with some modifications.

Recommendations
Currently, the structure is highly functional for wildlife passage on the west side of the river, but remains largely non-functional on the east side. A pathway through the riprap would improve passage opportunities on the east side.

Figure 84. View from beneath south structure

Figure 85. WSDOT staff and researcher in front of bridge

Figure 86. Riprap banks on east side of river

Figure 87. Dirt, rocky area on west side of river

Figure 88. East side median

Monitoring Results

I-90 Cle Elum River Bridge (Bullfrog Bridge)

This bridged structure is actually two bridges, each one accommodating opposing lanes of traffic. The median is naturally vegetated. The Cle Elum River runs through the site. There is no wildlife exclusion fencing present. WSDOT records indicate Average Daily Traffic is 26,547 vehicles, but a 15-minute count on a Friday afternoon in spring estimated 65,000 vehicles. There are natural forested areas on both sides of the west end of the bridge, west side of the river. The area to the east end of the bridge was not monitored, as there is little terrestrial passage opportunity. The area to the east is agricultural and cleared.

Two cameras were placed under the bridge on the west side of the river. One was placed along the south side of the bridge along the west side of the river, and a north camera was placed at the north bridge abutment. Both cameras faced inward toward the area under the paired bridges. Cameras were in operation from April 14 through October 21, totaling 189 days of camera coverage. The south camera was off 27 days in July and August. The north camera was on continuously. Mule deer results are below. There were 172 individual observations of deer at the site. These do not represent as many deer, but often in later summer and fall, these were repeat visits to the site by does and fawns. There were no obvious repels or parallel movements, see Table 7. The deer gender and ages of the animals photographed included: 95 does, 66 young, 6 bucks, 5 unknown. Males comprised 3.48% of passes recorded.

Table 7. Mule deer data tabulated for I-90 Cle Elum Bridge.

Camera Days Analyzed	Number of Deer Obs. at Site	Number of Deer Obs. per Day	Number of Successful Crossings through structure	Number of Deer crossing per day	Success Rate (%)	Rate of Repellency (%)	Parallel Rate (%)
189	172	0.91	172	0.91	100	0	0

Deer presence at the bridge was continuous through this phase of the study see Figure 89. In the 109 deer events recorded, 50(45.87%) occurred during daylight, and the remaining occurred at night or dawn or dusk.

Eight elk were photographed under the bridge in April in May. These consisted of four cows, two calves, one male, and one unknown. There was a multitude of other species of wildlife photographed at the bridge. Table 8 presents the animal species and the number of events with those animals. Human presence of the area was fairly regular, with 17 events. This is the site where a car crashed in the Cle Elum River directly in front of the South camera. Other human uses of the area include swimming, hiking, fishing, and WSDOT maintenance ranging from trash pickup to cranes coming under the bridge for upkeep.

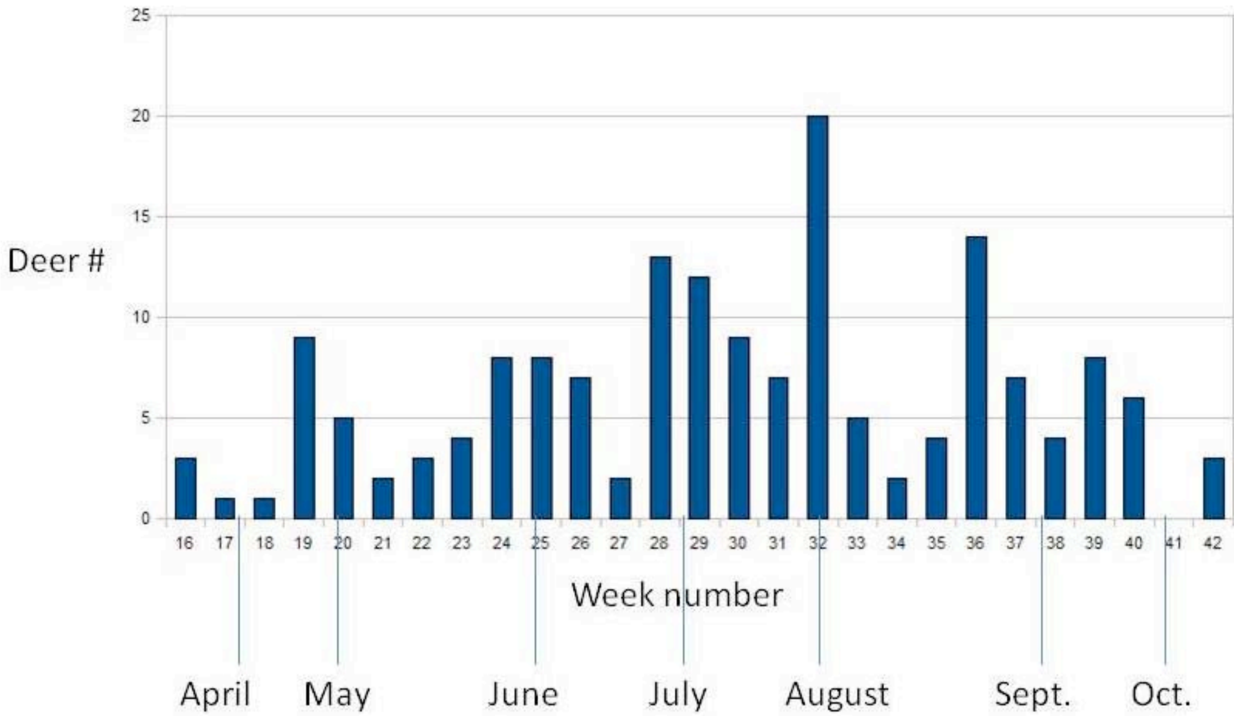


Figure 89. Mule deer passes per week at I-90 Cle Elum Bridge over the weeks of monitoring in 2010.

Table 8. Species detected at the I-90 Cle Elum Bridge and the number of events for that species.

Species

Mammals
- Humans - 17 events
- Humans with dogs - 2
- California Ground squirrel - 11
- Elk - 4 events, 8 animals
- Raccoon - 7
- Chipmunk - 2
- Porcupine - 1
- Red squirrel - 1
- Wood rat - 1

Birds
- Rock dove - 24
- Crow - 3
- Canada geese - 1
- Mallard duck - 1
- Raven - 1
- Robin - 1

Figure 90. Elk at south side of I-90 Cle Elum bridge.

Figure 91. California ground squirrel on north side of I-90 Cle Elum bridge.

Figure 92. Mule deer buck and doe on south side of I-90 Cle Elum Bridge.

Figure 93. Mule deer fawn looking up to I-90 on north side of the Cle Elum Bridge.

Figure 94. Canada goose and goslings under I-90 Cle Elum Bridge.

Figure 95. Porcupine entering area under I-90 Cle Elum Bridge, north side of bridge.

Location Name: Tucker Creek MP 73 Double Box Culvert

Location ID: 90_73_14
Route: I-90 ***Milepost***: 73

Roadway & Site Description
This segment of Interstate 90 is an east-west running, 4-lane divide highway (2 lanes in each direction). The surrounding landscape is semi-natural, forested with nearby residential development.

Structure Description
Type: Concrete Box Culvert Underpass
Structure Functional Class: Class 2 (medium underpass)
Dimensions: 4'10" high x 9' span* x 58'3" long

The structure is composed of two separate two-chambered concrete box culverts. There is a grassy, wet median (approximately 35' wide) separating the two structures. A small stream flows through the structures. The stream flow flattens out as it passes through the structure. There was no dry pathway all the way through the structure, although the water level was low and slow-moving at the time of the evaluation. The stream likely dries up partially by mid-summer, leaving more dry passage in both chambers. Similarly, dry pathways will likely be completely obliterated during high water events. The substrate through the structure is muddy and without rocks or gravel. A railroad runs parallel to the interstate on the south side of the structure, where the stream is channeled through an additional box culvert.

The surrounding habitat on both the north and south sides of the structure is largely forested. There are no obstructions or debris at any of the culvert entrances. Visibility through the structure is clear, but little light enters into the structure and there is a high light contrast compared to the daylight outside of the structure.

Barbed-wire right-of way fencing is present on both the north and south sides of the structure for the entire roadway segment. In addition, there is a guardrail immediately above the structure itself. There is no evidence of human activity at this location.

Wildlife
Deer tracks were observed at both the north and south side entrances; any possible tracks inside the structure or in the median would be obscured by the water flow. A live deer was also observed approaching near the north-side entrance. Raccoon tracks were inside the west chamber of the south structure. Very high traffic volumes on the interstate (25,000 to 65,000 average vehicles per day) acting as a barrier are likely to incentivize deer and other animals to use these structures to the extent possible, despite the limitations. Raccoon tracks were inside the west chamber of the south structure.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for Moderate Mobility Small Fauna and Adaptive High Mobility Fauna, meaning that the field evaluators concluded that animals from each of these guilds could successful pass through this structure as is or with small modifications. The structure received a 'C' rank for High Openness High Mobility Carnivores, indicating that the structure could be modified to be made functional for species of these Movement Guilds.

This structure received an 'F' rank for Adaptive Ungulates and Very High Openness Fauna – this ranking may seem contrary to the evidence of deer usage of the structure, however, the structure is only minimally functional for these animals as a result of the high traffic volumes, which leave no other option for accessing habitat bisected by the interstate. Use of the current structure by these species is likely limited to resident animals that have adapted to the only available passageway. To truly provide functional connectivity at this location for species in these Movement Guilds, a new, larger structure is needed.

The structure also received an 'F' rank for Low Mobility Small Fauna. The structure may be functional for some species in this group during certain times of the year (e.g., hydrophilic frogs during the wet season), but due to the ephemeral nature of the stream flow and the lack of riparian banks through the structure, there is no consistently reliable habitat through the structure year-round.

Recommendations
The existing structure is insufficient for Adaptive Ungulates and Very High Openness Fauna and would have to be replaced with either a larger single-chamber box culvert, a large double box culvert, one side for stream flow, the other for overflow and more terrestrial passage, or an arch or bridge structure to provide a suitable passage for animals in these groups. The roadway could be gradually raised from both sides to accommodate the greater height of a new structure.

Barring replacement, the structure could be marginally improved by the following retrofits:

- Install a shelf through the culverts or buildup sediment on one side of the structure to provide a consistent dry pathway all the way through the structure during all seasons.
- Plant bushes in the median to provide better cover and insulation from highway traffic noise and lights.

Figure 96. South side outlet

Figure 97. Semi-dry path through west chamber of south structure, with raccoon tracks

Figure 98. Median

Figure 99. Adjacent culverts and infrastructure just beyond the south side of the interstate (under road & railroad)

Figure 100. Deer tracks at north-side inlet

Monitoring Summary

I-90 Mile Post 73 Double Box Culvert

There is a small stream through these double box culverts. There is an open median area. There is forested vegetation away from the right away, with grassy areas extending from the highway to the forest. There is no wildlife fencing to "guide" animals to the culvert. WSDOT estimates Average Daily Traffic is approximately 26,000 vehicles, but field estimates have put the value closer to 65,000 vehicles. Two cameras were placed at this double box culvert, each facing into the entrance of the culvert on each side of the highway.

Cameras were in operation from June 23 through October 21, totaling 120 days of coverage. There were 226 mule deer observations at the culvert, meaning these are the number of individual deer that were photographed. Although the total numbers include 143 females, 28 males, and 55 young, these pictures were often the same animals. It is estimated from viewing the photos that there were approximately six to seven bucks, and approximately six does and fawns. Of the 28 buck photos at the entrance, nine of the animals (32.14%) were repelled. Males comprised 9.70% of the successful passes recorded. For further numbers please see table below. The number of deer at the site peaked from the last week of June through the last week of July, see figure below. This number correlates with the period of time when the fawns of the year begin to follow the does through the culvert, which began July third. This period of time is also when 60% of the bucks appeared at the entrance to the culvert. Table 9 presents the success and repellency rates for deer at this site.

Table 9. Mule deer observation data tabulated for I-90 MP 73 double box culvert.

Camera Days Analyzed	Number of Deer Obs. at Site	Number of Deer Obs. per Day	Number of Successful Crossings through structure	Succesful Deer Crossings per day	Success Rate (%)	Rate of Repellency (%)	Parallel Rate (%)
120	226	1.89	196	1.63	86	11	3

In the 156 deer events recorded, 75(48.08%) occurred during daylight, 69 (44.23%) occurred at night, and 12 (7.70%) occurred at dawn or dusk. No other ungulates were photographed at the culvert site.

There were several other species of wildlife photographed at the culvert. Below, Table 10 presents the animal species and the number of events with those animals. Human presence of the area was fairly regular. There were 22 events where humans came through the culvert, in all but two cases they were riding motorcycles and atvs.

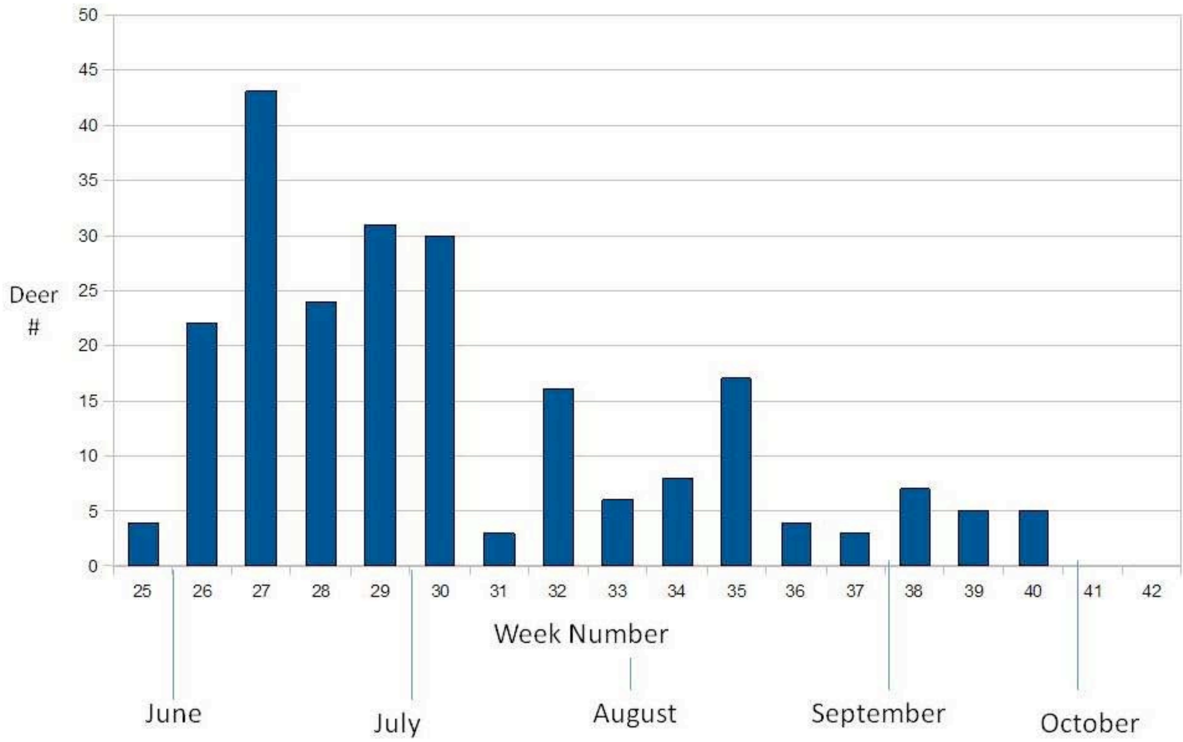


Figure 101. Mule deer passes per week at I-90 MP 73 box culverts over the weeks of monitoring in 2010.

Table 10. Species detected at the I-90 MP 73 double box culvert and the number of events for that species.

Species

Mammals

- Humans - 22 events
- Cat - 21
- Raccoon - 8
- Rabbit - 5
- California ground squirrel - 1
- Skunk - 1

Figure 102. Mule deer bucks pondering I-90 MP 73 culverts. They repelled away from structure

Figure 103. Mule deer brings fawn through the structure under I-90 at MP 73 for the first time.

Figure 104. Mule deer bucks entering and using culvert on I-90 MP 73.

Figure 105. Mule deer doe and fawns coming through structure under I-90 at MP 73.

Figure 106. Skunk using I-90 MP 73 culvert..

Figure 107. Typical motorized vehicle use of culvert under I-90 at MP 73.

Location Name: MP 33 Large Span Bridge

Location ID: 90_34_15

Route*:* I-90 ***Milepost***: 33.2

Roadway & Site Description

This segment of Interstate 90 is an east-west running, 4-lane divide highway (2 lanes in each direction). The surrounding landscape is semi-natural, forested with nearby residential development.

Structure Description

Type: Concrete Bridge Underpass

Structure Functional Class: Class 3 (large underpass)

Dimensions: 30' high x 58'7" span* x 80' long

**Span measured as functional distance between support walls.*

This location has two structures – one under the eastbound lanes and another under the westbound lanes. Both structures are large span bridges with concrete support walls and sloping dirt side slopes (2:1 slope). A 2-lane road runs parallel to the interstate on the north side of the structure.

A wide dirt/gravel recreational trail runs through the center of the structure. There is some grassy cover through the structures on either side of the trail. Grass/shrub leading into forest cover is present at both entrances on either side of the trail. The trail receives regular use by walkers, joggers, cyclists and, presumably, dogs. Nearby neighborhoods are present on both the north and south sides of the interstates, and the evaluators also found evidence of night-time use and partying at the site.

A 145' vegetated median separates the two structures and provides partial bush/tree cover along both sides of the recreational trail. Barbed wire fencing connects the two structures through the median, however large gaps in the fencing do not provide a continuous barrier to wildlife access to the median.

Six to eight foot high chain link fencing extends along the interstate in both directions from the structure, though it contains many gaps along its length. The fencing on the southeast side of the structure is 4'-high barbed wire rather than the taller chain link. A large gap in the fence has evidence of elk passage with an ungulate trail with elk scat leading through this gap and providing access into the highway right-of-way. Guardrail is present immediately above the structure itself.

Wildlife

Elk scat was observed on an ungulate trail that crosses through a gap in the fencing on the south side. A road killed rabbit was also observed on the highway.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This location received an 'A' rank for all species movement guilds except Low Mobility Small Fauna, for which it received a 'C' rank, meaning that this structure is suitable with small modifications for all types of species, though it could be improved to also be functional for Low Mobility Small Fauna.

Recommendations
The existing primary limitation at this structure is the level of human activity, which may deter some wildlife activity, if they are not habituated to human presence, and the serious gaps in the existing fencing, which are likely to cause animals to become trapped inside of the highway right-of-way.

The following improvements are recommended to increase the efficacy of this structure for wildlife passage:
- Add cover and down logs through the structure and the median to improve crossing habitat for Low Mobility Small Fauna.
- Repair gaps in fencing and replace barbed wire fencing on south side with 8'-high chain link or wildlife fencing.
- Night-time policing to minimize human activity during the night hours when wildlife could be encouraged to use the structure.

Monitoring Summary

I-90 MP33 Bridges
Two cameras were installed at this site on April 15 and 16, 2010. The initial day and night of monitoring revealed only human passages through the structure. By the third night, the camera utility boxes were broken into and the cameras were broken and stolen. This ended monitoring at this site. A camera was later recovered in a nearby river several months later.

Figure 108. View from north side of slope highway

Figure 109. Support wall and side of north structure

Figure 110. Gap in chain link fencing on south side

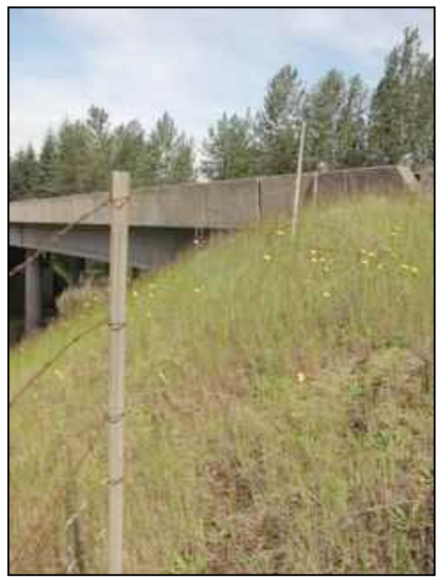


Figure 111. Large gap in barbed wire fencing through median

Location Name: Snoqualmie River Bridge, North Bend

Location ID: 90_30.5_16
Route: I-90 ***Milepost***: 31.5

Roadway & Site Description
This segment of Interstate 90 is an east-west running, 4-lane divide highway (2 lanes in each direction). The surrounding landscape is largely forested.

Structure Description
Type: Concrete Bridge
Structure Functional Class: Class 4 (extensive bridge)
Dimensions: 6'10" high x 90' span* X 95' long

> **Height and span measurements refers only to the eastern-most span of the north structure, where it spans the trail. The full structure is too large to measure directly.*

There are two structures at this location; one under the eastbound lanes and another under the west bound lanes. Both structures are large concrete bridges with three concrete support walls. The Snoqualmie River flows under both bridges. The bridges are parallel to one another and separated by 223'-wide vegetated median and the river. There is minimal vegetation (some grasses) beneath the structures themselves, but extensive Himalayan blackberry along the river banks at both ends of the structure which may limit wildlife movement along the banks. Visibility through both structures is very high.

The bridge spans the river as well as the banks and a substantial amount of upland area on either side of the river. A recreational trail runs through the east side of the structure, and the high banks are reinforced with riprap, which may prevent animals from accessing the upland trail from the river. However as people regularly use the trail (which provides access for the adjacent neighborhood), wildlife may be largely disinclined from sharing the trail during daylight hours. The trail appears to receive daily use by walkers/joggers and dogs.

Eight-foot tall chain link fencing is present on both the north and south sides of the structure. The fencing ties into the structure both in the median and at the ends of the bridge. The fence extends east and west along the highway for at least a mile. On the south side of the westbound bridge, in the median area, it is present only intermittently with large gaps allowing wildlife access to the median, and there is a game trail leading directly up to the highway.

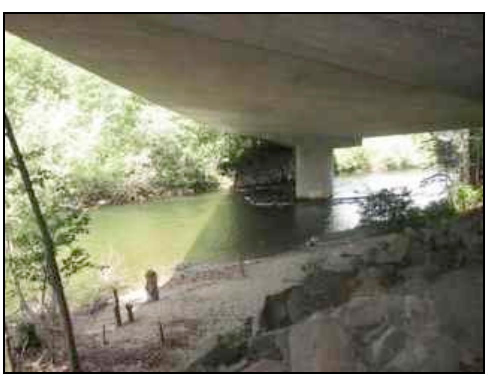
Wildlife
A mule deer was observed crossing through the structure from west to east at the time of the assessment. A lone doe crossed moved along the shallows to the riparian vegetation on the other side. Where the vegetation got particularly thick with Himalayan blackberry she swam across the river and exited on the other side. This observation was particularly interesting because no deer tracks were observed on

the riparian banks through the structures, where numerous dog and human tracks were observed. The animal instead chose to walk through the shallow water. Deer tracks were also observed on the trail 30 feet from the structure entrance. During an earlier visit when the monitoring cameras were installed, elk tracks were also observed.

Species Movement Guild Rankings
This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This structure received a 'C' rank for Low Mobility Small Fauna because of the lack of continuous riparian habitat through the structure. The structure received an 'A' rank for all other species movement guilds, indicating that animals from each of the Movement Guilds could successful pass through this structure as is, although passage could be further enhanced with some modifications.

<u>Recommendations</u>
Currently, the structure is highly functional for most wildlife, although regular human activity may limit some wildlife passage. The following recommendations would enhance successful crossings:

- Repair gaps in fencing and escape ramps for extensive stretches of fencing.
- Improve stream bank habitat on both sides of the river. Establish a riparian access area for people and their pets away from the structure and inhibit such human/dog activity directly under the structure itself.
- Control Himalayan blackberry brambles so wildlife can move through the riparian vegetation and their movements can be separated from recreationists and dogs on the trail.
- Add soil pathways over the riprap on both sides of the river (at least one pathway under each structure and in the median).



<u>Figure 112</u>. Beneath north structure

<u>Figure 113</u>. Trail under north structure

Figure 114. Riprap on west bank

Figure 115.Thick vegetation through median

Figure 116. Chain link fencing

Figure 117. Doe crossing through structure along water's edge

Figure 118. Doe jumping through brambles before swimming to opposite bank

Monitoring Results

I-90 at Snoqualmie River

Two cameras were installed under this bridge on April 15, 2010. They were positioned behind the existing chain link fence because the area is used as a trail by local citizens, thereby increasing the cameras' vulnerability to vandalism. Cameras pointed toward the trail near the median on the east side of the river. The area is known to be frequented by local elk headed to and from a golf course on the south side of the highway. On April 17 three cow elk were photographed moving under the bridges at this site (see photos below). No other wildlife was photographed. On the night of April 17 the pair of cameras nearby along the King County Trail were vandalized and stolen. On the night of April 18 several suspicious individuals were photographed at this site at 3:00 in the morning. These cameras were pulled immediately to protect them from theft. The elk photos are a major finding of this study. This is one of two places in this study where elk have been photographed successfully passing through a structure. The bridge is less than seven feet high where the elk traversed underneath, and over 20 feet high where the structure straddles the Snoqualmie River. Regardless, the section where elk moved through is among the lowest recorded heights for structures that elk have used in the United States. The fact these elk are habituated to humans in the North Bend area may make them more apt to use this type of structure.

Figure 119. Cow elk passing under I-90 bridge over Snoqualmie River outside of the town of North Bend.

Figure 120. Three cow elk passing under bridge for I-90 over Snoqualmie River, near North Bend, WA.

Location Name: I-90 MP 29 Corrugated Steel Culverts

Location ID: 90_29_17

Route: I-90 ***Milepost***: 29

Roadway & Site Description

This segment of Interstate 90 is an east-west running highway with four lanes of westbound traffic and three lanes of eastbound. The surrounding landscape is densely forested.

Structure Description

Type: Metal Arch Culvert

Structure Functional Class: Class 3 (large underpass)

Dimensions: North Structure: 12' high* x 29' span X 120' long
South Structure: 12' high* x 29' span x 144' long
**Estimated height; not measureable.*

There are two structures at this location; one under the eastbound lanes and another under the west bound lanes. Both structures are large arch culverts with natural dirt bottoms separated by a 180'-wide vegetated median. Visibility through both structures is high, although the culverts allow limited natural light, so there is a high light contrast inside the structures relative to outside daylight. A small ephemeral stream slows through the south structure, but is buried under the structure, reemerging in the median and the north structure. Both culvert bottoms slope towards the south, the north culvert to a greater degree. Forest cover is abundant at both structure entrances.

Eight-foot tall wildlife fencing with a 6x6" mesh connects the two structures through the median and extends in each direction along the roadway for an unknown distance. The fence appears to be in good overall condition, although there is a small gap between the ground level and the bottom of the fencing through the median, and the fencing is not completely connected to the structure at all edges.

There were no apparent signs of human activity at either structure, although domestic dog tracks were observed.

Wildlife

A number of tracks were observed inside both structures, including raccoon, black bear, fox and coyote. Bear scat was also found in the median area. A western toad and multiple slugs were seen in the structure at the time of the inventory. While no elk tracks were observed around the structures, they were seen along the above roadway.

Species Movement Guild Rankings

This site was identified by WSDOT biologists as important for species in each of the Movement Guilds. This structure received a 'C' rank for Low Mobility Small Fauna because of the lack of continuous habitat and structure through the structure. The structure also received a 'C' rank for Adaptive Ungulates and Very High Openness Fauna because the structures are quite long and enclosed for species in these groups. The structure received an 'A' rank for all other species movement guilds, indicating that animals from each of the Movement Guilds could successful pass through this structure as is, although passage could be further enhanced with some modifications.

Recommendations

Currently, the structure is highly functional for a wide variety of wildlife. The following recommendations would enhance successful crossings:

- Repair gaps in fencing and escape ramps for extensive stretches of fencing.
- Add down logs to enhance structural complexity through the structure for Low Mobility Small Fauna. Monitoring data revealed use by carnivores but no raccoon, fox, skunk, rodents, or smaller wildlife which may be threatened by continuous carnivore presence. Even the researcher checking the cameras could smell the bear presence.
- Instead of burying the small creek as it passes through the structures, allow it to meander through the structure – perhaps by building up the grade further upslope – to provide additional habitat for Low Mobility Small Fauna and to enhance the structure's appeal for other species.
- Control the spread of invasive species around the structure.

Figure 121. South structure entrance

Figure 122. View from structure outlet

Figure 123. South structure, with unconfined flow

Figure 124. North structure outlet

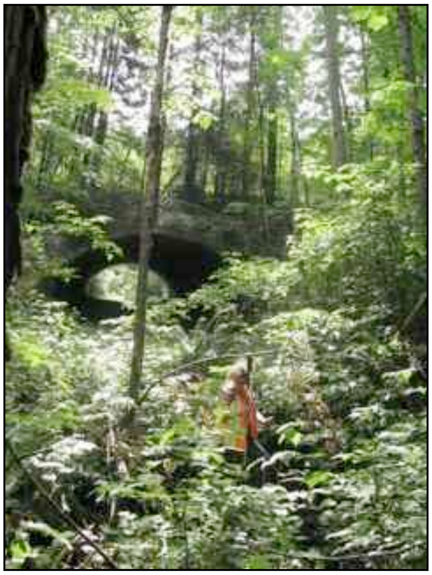


Figure 125. Thick median vegetation

Figure 126. Western toad

Figure 127. View from north structure outlet

Figure 128. Westbound roadway

Monitoring Results

I-90 Mile Post 29 Corrugated Steel Culverts
This dense forest location is just west of Bend, Washington. The culvert lies in an area that is heavily vegetated and forested, with no obvious human paths or roads to or near the area. There is a heavily vegetated median between the culverts and a small stream entering the culvert at the south (uphill) side. The stream is diverted to an underground culvert and reappears in the median. It then runs over the surface through the north culvert. There is eight feet high (2.4 meters) wildlife exclusion fencing made of chain link present at the site. The Average Daily Traffic for this area is 51,500 vehicles. Two cameras were placed at this pair of large steel culverts, on June 23, one on each entrance. Wildlife use was fairly consistent throughout the

monitoring period, with a high of 14 wildlife events in July, and a low of eight wildlife events in September.

In 120 days of monitoring, this culvert proved to be a heavily used by black bear. There were 31 black bear observations in 21 events. Of those, there were five events where a sow and two cubs were observed moving through the culvert. There were one to several yearling sized bears, and three distinct large bears, possibly males. On one occasion, a bear was repelled, otherwise, all bears moved through the culvert. Bear use during the daylight hours occurred in 60% of the bear passes.

Mule deer were observed in three events: all events involved a doe and two fawns. They went through the culvert on two occasions. On the third occasion the doe was photographed on the road right of way on the other side of the fence while the fawn was below at the entrance to the culvert. The three deer events occurred during dawn (1), day (1), and dusk (1). No bucks were photographed.

Single coyotes were observed at the cameras on 19 occasions. Their use of the culvert was not always definite. There were three occasions where the coyote repelled, and four occasions where the coyote paralleled the culvert. Of the 19 coyote observations, only four (21%) occurred during the day. Bobcat was observed on three occasions, and the animal(s) moved through the culvert on each one. All bobcat observations occurred at night. Total numbers for each species are presented in Table 11. Humans were observed in three events, all during daylight hours.

Table 11. Species detected at the I-90 MP 29 corrugated steel culvert and the number of observations for that species.

Species

<u>Mammals</u>

Black bear - 31
Coyote - 19
Mule Deer - 6
Bobcat - 3
Humans - 3

Figure 129. Black bear sow moving through I-90 culvert at mile post 29. First of two.

Figure 1300. Black bear cubs following mother through I-90 culvert at mile post 29. Second of two.

Figure 131. Coyote being repelled from culvert, south entrance, under I-90, mile post 29.

Figure 132. Black bear entering north end of culvert under I-90 at mile post 29. Ultimately bear went through.

Figure 133. Mule deer and young exiting culvert under I-90 at mile post 29.

Figure 134. Bobcat entering culvert under I-90 at mile post 29.