Understanding Barrier Effects and Crossing Designs

**BUCKSHOT VERSUS THE SILVER BULLET, A REGULATORY PERSPECTIVE: UTILIZING LOW COST WILDLIFE FRIENDLY DESIGNS EVERYWHERE VS. CONSTRUCTING A FEW EXPENSIVE CROSSINGS**

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**ABSTRACT**

The Minnesota Department of Transportation (MnDOT) and the Minnesota Department of Natural Resources (DNR) has been working within agreements set forth in an interagency Memorandum of Understanding (MOU) for each department to provide thorough knowledge of the other's programs and projects in order to evaluate possible impacts and identify opportunities for collaboration. This has resulted in an increase in environmental compliance, increased consistency, and reduced delay of project timelines. One unforeseen product of these agreements has been the development of a 'Best Practices' guidance manual for meeting state environmental regulations. This manual is an incentive based guidance document and is being utilized as a comprehensive communication tool and implementation guide for the designer, construction manager, and contractor.

This manual has typical procedures and examples of how to address various issues relating to natural resource regulations. While much of these ‘Best Practices’ provide guidance on meeting permit provisions, other portions offer illustrations of recommended construction practices and also provide typical designs that can mitigate construction impacts to ecological resources in the project area. These include simple engineered design modifications to allow for riparian continuity at roads, as well as curb and storm drain design to reduce animal mortality on curbed roads, selection of native vegetation for roadsides, invasive species control, and hydrologic improvements. Many are now typical designs that are being applied to the road infrastructure in non-regulatory situations, substantiating that this manual has a set of design combinations and incentives that benefit the interests of both transportation and environmental agencies.

**BACKGROUND**

The Commissioners of the Minnesota Department of Transportation (MnDOT) and Department of Natural Resources (DNR) originally signed a Memorandum of Understanding (MOU) between the two agencies in 1971. Since then, the MOU has been updated several times, most recently in 1999. A major purpose of the MOU is for each department to be provided thorough knowledge of the other's programs and projects in order to evaluate possible impacts and/or opportunities for collaboration. The MOU and its current usage direct the two agencies to look for streamlining opportunities while at the same time assuring that there is a value added process as well as consistency of regulatory applications across the state in dealing with issues affecting the two agencies. In 2001, a pilot ‘Transportation Team’ project was funded by MnDOT. The DNR Team consisted of a Planner, an Ecologist, and a Hydrologist. This team conducted environmental reviews and permit reviews for MnDOT's projects statewide. It also began an effort to provide incentives for ‘what can be done’ rather than the conventional ‘what can’t be done’ regarding regulatory constraints. This pilot project ended in 2003. However, a single position of ‘DNR Transportation Hydrologist’ position continues to this day through an Inter-Agency Agreement. The position is an agency liaison position and acts on the behalf of many DNR programs for all MnDOT Transportation projects.

One of the most important aspects of the Transportation Hydrologist position is the freedom to act independently and make accountable decisions within the framework of departmental policy and legislative mandates. The freedom to act is necessary to enable the Transportation Hydrologist to solve complicated and controversial issues, negotiate effective
compromises, enforce regulatory mandates, develop creative and innovative solutions, and serve the public as a representative of the DNR in an efficient and effective manner. The Transportation Hydrologist has been delegated the regulatory authority to issue most public waters and appropriation permits pertaining to MnDOT transportation projects. This position has the authority to communicate directly with stakeholders and negotiate resolutions to problems, certify regulatory compliance, develop grant opportunities, set priorities, and coach resource management activities meeting DNR objectives. Because of the sensitivity associated with water resource issues, decisions and actions by the Transportation Hydrologist has resulted in statewide significance. An important tool has been the continued incentive based integration of ecological concerns with transportation needs that began with the ‘Transportation Team’. This tool is the manual ‘Best Practices for Meeting DNR General Public Waters Permit GP2004-0001’.

THE BEST PRACTICES MANUAL

The manual ‘Best Practices for Meeting DNR General Public Waters Work Permit GP2004-0001 (MnDOT Projects with Bridges, Culverts, or Outfalls)’ has been developed to be utilized as a guide to address DNR regulations and rules for protection of water resources for fisheries, wildlife, ecological systems, rare features, and recreational opportunity. It is an open document that is continuing to evolve. It also recognizes that other technical references, standards, and regulations may apply. However the manual is referred to during the evaluation, design, and construction phases of transportation projects.

The manual was originally developed for meeting specific provisions of the Minnesota Department of Natural Resources (DNR) General Public Waters Work Permit (GP) 2004-0001. This general permit has been issued to MnDOT for the repair or reconstruction of culverts, bridges, or stormwater outfalls impacting Public Waters. Its current use is much broader than originally intended. County and local road authorities now also look to this manual for guidance to meet the state environmental regulations. The latest version of the manual includes a growing number of best practices to protect not just the ecology of Public Waters, but also many terrestrial ecological concerns that DNR oversees. Some Best Practices in the manual are for guidance in design, others illustrate recommended construction practices. The manual is only available electronically and thus information can easily be copied and inserted directly into project documents and construction plans. The information in this manual is not to be considered the only method for which a project may be designed and constructed. However its ease of use is an incentive to apply it into a project in order to meet DNR regulatory requirements.

The manual’s focus is on state regulatory requirements of the DNR Public Waters Permit process. Public Waters are designated as the lakes, wetlands, and watercourses over which DNR has regulatory jurisdiction. It is recognized that the manual does not contain enough information to release the user from requirements of any rules, regulations, requirements, or standards of any applicable federal or state agencies; including, but not limited to the, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, other MN Department of Natural Resources programs, Board of Water and Soil Resources, Minnesota Wetland Conservation Act, MN Pollution Control Agency, or Watershed Districts. However during its development there have been efforts to integrate many requirements of other agencies, such as the Minnesota Pollution Control Agency’s General Permit for Authorization to Discharge Stormwater Associated with Construction Activity (MN R100001) and the DNR Temporary Appropriations for Construction Dewatering General Permit (GP 97-0005). With agency collaboration on the practices in this manual, the likelihood of them meeting other agency requirements is very high. This adds incentive for its use, and a comfort level for the project manager with tight project timelines.

The manual is organized into four chapters. It is to be utilized as a comprehensive communication tool and implementation guide for the designer, construction manager, and on-site contractor. Pages show needed steps, checklists, procedures, or examples of how to address various issues and to meet regulations. It is considered as a sample plan for DNR constraints near a watercourse, lake, wetland or rare feature. During early inter-agency coordination of a project, as identified in MnDOT’s Highway Project Development Process (http://www.dot.state.mn.us/planning/hpdp/scoping.html), DNR will identify which best practices should be incorporated into project documents for guidance to meet DNR regulations. The entire document is not expected to be incorporated into every project. In fact, each Best Practice is written to be utilized as a stand-alone document. With early project communication between MnDOT and DNR, appropriate Best Practices are identified as being applicable to a specific project.

- **Chapter 1 (Species Protection)** provides information about protection of game fish, other aquatic or terrestrial species and sensitive native vegetation. There is also guidance to prevent the spread of invasive species. This chapter also contains many options for ecological enhancements and/or protection to include in final design or construction methods. Much of this guidance is required under permit conditions, and if not, can qualify for mitigation measures for a projects impact to resources in the area.
• **Chapter 2 (Hydraulic and Hydrologic Recommendations)** contains several detail illustrations, notes and guidance of Best Practice options for Hydraulic and Hydrologic design of structures impacting Public Waters. Additional information is also provided to improve or repair stream stability and local habitat.

• **Chapter 3 (Methods of In-stream Construction)** offers illustrations, notes, and guidance on best practices for in-water construction work. These methods have been pre-approved by the DNR for use in the field; however, not all methods are appropriate for all work sites. Due to the variability of concerns from one work site to another site the DNR Hydrologist will have to approve a method prior to construction. For this reason project designers, construction engineers, project managers, or contractors work in consultation with the DNR for selection and approval of the appropriate method of in-water construction. It should be pointed out that the DNR will authorize a project's final design prior to a project going to bid, with the details for construction to be approved at a later date (after the contract is awarded).

• **Chapter 4 (Examples of Worksite Sediment and Erosion Control)** focuses on photos and examples of best practices for erosion and sediment control in or adjacent to Public Waters. Most erosion and sediment control requirements have been developed by the MPCA; however, these field examples show proven methods to meet them.

• **Appendix (Contacts, Permits, and miscellaneous documents)** contains copies of contact lists, permits, and typical specifications related to material in the manual.

**THE ‘BUCKSHOT’ APPROACH**

The first two chapters of the manual contain thirteen (13) Best Practices that provide guidance on available methods for protecting or enhancing ecological and water resources. Very few of these are expensive, and in fact some add no cost to a project at all. Many of these practices have not been quantitatively studied for their true environmental effectiveness. However, collectively they do show evidence of success.

• **Chapter 1: Species Protection**
  - Work Exclusion Dates to Allow for Fish Spawning and Migration
  - Spawning and Migration Behavior of various fishes
  - Best Practices for prevention of Spread of Invasive Species
  - Protective Measures for Areas of Environmental Sensitivity
  - Information Transplanting Wildflowers and other Plants
  - Selecting a Seed Mix
  - Passage Bench Design
  - Environmental factors of Curb Design
  - Looming issue with Loose Net Plastic Mesh in Erosion Control Products
  - Birds and Bridges
  - Reducing Wildlife – Vehicle Collisions
  - Compost Grouting (Riprap Seeding)

• **Chapter 2: Hydraulic and Hydrologic Recommendations**
  - Fish Passage and Notes on Culvert Design Criteria

In Minnesota our topography is relatively flat and does not have terrestrial migration corridors that would lend themselves to large wildlife crossing structures. For example, the state’s population of white tail deer tends to be everywhere and is able to go anywhere. Identifying a suitable location for a large structure to accommodate deer movement under or over a road location would be difficult if not impossible. Yet we do have three major ecosystems (prairie, northern coniferous forest, and hardwood forest), all of which support differing fish and wildlife species that may be compromised by road systems. With Minnesota’s abundance of lakes, rivers, streams and wetlands, we have focused on the riparian corridor and have developed a ‘buckshot’ approach utilizing multiple low cost designs in order to maintain or restore ecological integrity. Project designers benefit from having this set of typical design specifications by being able to incorporate these low cost measures into road design early in the process for either mitigation purposes or regulatory requirements of environmental agencies. The ease at which these pre-approved practices are available is an added incentive for their use. Many are now typical designs that are being applied to the road infrastructure in non-regulatory situations, substantiating that this manual has a set of design combinations that benefit the interests of both
transportation and environmental agencies. While many practices are small, and often low cost, such a combination is leading to practices being applied many times over a large geographical area. We feel this approach will result in a significant improvement in reducing a road networks impact on natural resources of the state.

Examples

Many designs have been developed with several benefits in order to appeal to multiple interests. The following are just a few.

The Passage Bench

This bench is an alternative design in the riprap under a bridge that mimics a game trail. A one meter (3 foot) wide bench or trail is incorporated into the specified riprap, and then gravel is added to fill voids in the riprap bench. This bench is carried through the riprap and is tied to the natural groundlines outside the bridge. A biologist considers this bench as a ‘critter crossing’. A bridge inspector considers it a feature to ease bridge inspection (same with the bridge maintenance crew). A hydrologist can utilize the design to adjust normal channel flow and flood flow characteristics, similar to that of a notched weir. Road safety engineers consider it a beneficial design since animals are not forced up and over the road at the bridge approach panels. Finally, it costs very little, which appeals to those overseeing the budget. With these multiple benefits, the design has received support due to its broader applications and has gone from an experimental practice to a standard design in just a few years.

Curb Design

Ecological factors of curb design are also a noted Best Practice. Traditional curb and gutter can and does inadvertently direct small mammals and reptiles into the storm sewer. Small animals trying to leave the road can be blocked by the steepness and height of the curb and they will travel parallel to it until they find an exit. The storm sewer is the exit they literally fall into, often with fatal consequences. Our remedy does not require a custom design. By pointing out just two typical designs options that already exist as a MnDOT standard design, such as an angled curb or a drop structure design without the side box inlet, roads can provide animals a better chance of moving past the storm sewer to seek a safe way off the road. To the ecologist this allows small animals to leave the road surface at any point. Yet to the road designer, it still provides for an approved method for the collection of stormwater. It’s an easier task to request a road designer to utilize an appropriate curb design that already exists, than it is to request a custom design. Coincidentally, these two designs are increasingly being utilized due to reduced installation and maintenance costs. Thus there is a dual incentive for this practice.

Wildlife Fencing

The question of how to reduce the likelihood of Wildlife Vehicle Collisions (WVC) is regularly brought to our attention. However we do not have a definitive set of designs for reducing WVC along our roadways. The current Best Practice is to utilize ‘typical’ or ‘standard’ fencing designs in Minnesota. For small animals, chain-link fence installed tight to the ground is recommended. This is one of MnDOT’s ‘standard’ or ‘typical’ right of way fence designs. For seasonal fencing to protect reptiles and amphibians, standard erosion control fence may be utilized to hinder movement into construction sites, onto roads, or for redirection to safer crossings (nearby culverts or bridges). For deer, a high woven wire or chain link fence is being utilized. There is also a growing trend to utilize vegetation as a deterrent instead of fence (EG for goose control). Typical right of way fence designs were reviewed in order to determine to best option available. These are now recommended over custom designs in order to reduce costs, yet still reduce vehicle animal collisions.

Culvert Design

For decades Minnesota has required culverts to allow for fish passage. Traditionally, culvert design was based on hydrologic and hydraulic models that predict peak runoff from a watershed, with the culvert sized accordingly to pass a specified design storm. The DNR typically required that culvert velocities not exceed two feet per second for a two year event. However, these constraints were not always accomplished with this method. Several alternative design methods have been developed that focus on matching the natural characteristics, and consider sediment transport and fish passage requirements. Currently a variety of design techniques are increasingly being implemented in Minnesota. Minnesota is working towards a stream simulation approach as a standard design requirement; however, those efforts are still in progress. We do not yet have a standard method for design. One design that does have multiple benefits for terrestrial animals is the use of the offset culvert. One culvert is placed at an elevation to carry normal flows, and the other one is set at an invert that would be dry in normal flow conditions. This dry culvert allows for animal use in all
times except flood flow conditions. Thus this design allows for both hydraulic conveyance and animal use, at little or no extra cost over traditional double barrel installations.

Invasive Species

In order to prevent the spread of invasive species into and within the state, all equipment intended for use at a project site must be free of all ‘aquatic plants’ and ‘prohibited invasive species’ prior to being transported into or within the state. Best practices have been developed that are specific to construction equipment. This sheet is provided to all contractors working a project where invasive species have been identified.

Native Vegetation

Roadside re-vegetation is also an area that has seen changes lately. To date, the majority of native grasses and forbs being required are for wetland mitigation or for scenic benefits. Native seed mixes appropriate for roadsides are receiving renewed attention. There are several benefits, as native vegetation, if well managed, can help prevent weed infestations by providing a more competitive vegetation type, they can be used to increase road safety by catching snow to reduce drifting and blowing snow problems. Native grasses and forbs also have deeper root systems and can provide a more durable long-term erosion control solution than non-native grasses such as smooth brome. Some evidence suggests that diverse native plantings provide better stormwater infiltration than less diverse and non-native vegetation. These multiple incentives and secondary benefits can reduce opposition to their use.

CONCLUSION

In Minnesota you do not have to travel far before there is a need to cross some type of water feature. Many of the conventional water crossings are impediments to animal and fish movement. In the past, hydrology was the primary design criteria for these installations. Agencies such as MnDOT, DNR, and USFWS, along with various academic groups, have formed partnerships in order to better understand the complex ecological interactions of our road system, develop designs and practices to mitigate adverse impacts, and to develop incentives for incorporating them into transportation planning and construction. The Best Practices that were developed have been incorporated into a single manual: “Best Practices for Meeting DNR General Public Waters Work Permit GP2004-0001 (MnDOT Projects with Bridges, Culverts, or Outfalls)”. This manual that provides multiple design options in or near water that provide for ecological protection or improvement. These designs tend to be low cost methods to accommodate animal or fish passage, and ecological protection. These practices have been created to be integrated in multiple situations and are not site specific. Incentives for their incorporation into projects includes, low cost, confidence in a road design that will meet regulatory approval and have no delay in regulatory review and permitting, and multiple stakeholder benefits. With these incentives, multiple practices are being installed in many locations on a project and around the state. With this set of Best Practices being applied everywhere, we believe we are providing better ecological connectivity than focusing on just a few locations with site specific design. Cooperative efforts also continue to present opportunities for new designs and alternative practices.

BIOGRAPHICAL SKETCHES

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Landscape Features Associated to Roadkill of Three Mammal Species in the Brazilian Cerrado

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ABSTRACT

Mammals have been threatened by roadkill all over the world. In tropical regions, those casualties could represent biodiversity loss by increasing mortality rates or isolation of wildlife populations. This study aims to evaluate spatial patterns and landscape characteristics associated to causalities due to mammal-vehicle collisions. The study site was the highway (SP-225) in northeast of São Paulo State, Brazil. It is located in Cerrado biome with semideciduous forest and riparian vegetation, but land use is dominant in landscape, such as: sugar cane and orange crops, pasture and forestry. Roadkill surveys were done from January/2006 to February/2008 on a daily basis. We measured landscape features around (buffers of 1 km, 5 km and 10 km) the roadkill records of three selected species (Cerdocyon thous, Lepus europaeus and Chrysocyon brachyurus). Landscape features were the relative area of each land-cover and land-use classes (divided by buffer area). We used a logistic regression models for each species, thus the dependent variable was species presence and independent variables were landscape features relative area. For generate absence points, we sorted the same number of record of each species. The model selection was done by the Akaike’s Information Criterion (AIC). The roadkill survey recorded 114 mammals of 15 species. The two species most hit were Cerdocyon thous and Lepus europaeus, with 32 and 22 records respectively. Chrysocyon brachyurus, a threatened species to extinction, has 10 roadkill records. The best model selected to explain roadkill of Cerdocyon thous based on landscape features showed that it was higher in areas with more forestry and less urban. C. thous is an ecologically plastic animal, so it can adapt well to agricultural, deforestation and regeneration areas. Thus, the C. thous may be using forestry areas distant from urban areas such as route. Roadkill of Lepus europaeus occurred in areas with more forestry, more orange crops and with less native vegetation. L. europaeus can be benefit greatly from the expansion of agricultural areas and because the hare is a generalist herbivore, is often found in areas of planting oranges, sugar cane, among others. Thus, as expected, the roadkills of hare were more frequent near of their habitat: in plantations, far away of native vegetation. Roadkill of the threatened Chrysocyon brachyurus occurred in sites more urban and with less pasture. The landscape analysis of roadkills indicates where were the species’ preferential routes and habitats. As an endangered species, C. brachyurus, represents a special concern for conservation. C. brachyurus is an omnivorous and opportunistic, and could be attracted to urban areas, because of the garbage on the road side and the ease hunting of synanthropic animals. The roadkills in areas of less pasture may indicate less use to avoid cattle or fences, corresponding to occasional use in disturbed areas. Knowing landscape characteristics that “attract” animals to roads is relevant to decide the best solutions to mitigate roadkill, especially in tropics that needs a multi-species approach.

INTRODUCTION

One of the major concerns for conservationists is the issue of roads and disruption it causes to the environment causing genetic isolation at population level and biodiversity loss at community level (Benítez-López, Alkemade, and Verweij 2010; Roger, Laffan, and Ramp 2011; Van der Ree et al. 2011; Goosem 2007). Roads affect the atmosphere, soil, vegetation, fauna and human communities (Forman et al. 2003; Laurance, Goosem, and Laurance 2009). The roads lead to fragmentation of habitats and edge effects, cause landscape disturbances by vehicle traffic and gas emissions, facilitate colonization by invasive species, increase access to natural areas by humans, but the most conspicuous impact to the fauna is the increase of mortality caused by roadkills (Forman et al. 2003; Laurance, Goosem, and Laurance 2009; Goosem 2007; Barthelmess and Brooks 2010).

Mammals exhibit three types of behavioral responses to roads and traffic: (i) the avoidance of roads, (ii) the avoidance of atmospheric emissions and disturbances caused by roads, and (iii) the ability to escape from the vehicle (Jaeger et al. 2005). The first response decreases the rates of mortality but also decreases habitat connectivity, while the
emissions and disturbances reduce the quality of those habitats over the roads. On the other hand, the ability to avoid the vehicles is the behavior with a positive impact as it decreases the chances of being hit. Forman et al. (2003) considered that the worst type of response occurs when animals are attracted by roads, which increases the frequency of wildlife on roads and the risk of being killed.

Several factors influence the mortality caused by collisions with vehicles on roads, for example, biological characteristics, such as high vagility, and road characteristics, such as sinuosity, traffic volume and vehicle speed (Laurance, Goosem, and Laurance 2009; Goosem 2007; Forman et al. 2003; Grilo et al. in press). However, a large number of roadkills of a particular species does not necessarily imply a threat to the survival of this species, as it may well indicate that species is abundant in the area or has a wide distribution (Fahrig and Rytwinski 2009). On the other hand, even a low rate of roadkills may represent a significant loss in populations for rare, endangered or threatened species (Forman and Alexander 1998). In the case of mammals, body size, reproductive rate, diet and classes preferred for displacement are important characteristics that help to identify which species are most vulnerable (Cáceres in press; Barthelmess and Brooks 2010; Grilo, Bissonette, and Santos-Reis 2009; Rytwinski and Fahrig 2011). Larger animals have wide home range, and thus are more likely to find roads than smaller animals (Ng et al. 2004; Forman and Alexander 1998; Grilo, Bissonette, and Santos-Reis 2009). Specially in fragmented landscapes, large and medium-sized mammals explore the landscape as a whole not strictly to native vegetation, thus a landscape approach to understand road kill sites is needed (Lyra-Jorge, Ciocheti, and Pivello 2008). Diet also plays an important role, since herbivores typically have higher densities than carnivores and omnivores (Cáceres et al. 2010; Barthelmess and Brooks 2010). Many herbivores are attracted by the grass and seeds dropped by trucks along the edge of roads, as well as omnivorous animals are attracted by garbage dumped along the highways and carcasses of other hit animals (Forman et al. 2003).

Despite the great biological diversity presented by the Brazilian Cerrado, considered a hotspot (Myers et al. 2000), few actions have been taken for its conservation. The Brazilian Savannah is suffering great threat, due to expanding agriculture, building roads and dams, deforestation and urbanization (Carvalho, De Marco Jr., and Ferreira 2009). This land’s occupation leads to fragmentation and loss of native habitats, which is threatening many wildlife populations (Karanth and Chellam 2009). The fragmentation leads to changes in landscape structures such as the connectivity, thus, the tolerance to the matrix is a key ecological attribute for the maintenance of species in fragmented landscapes (Henle et al. 2004). So it is important to understand how the mammals use this landscape, and the permeability of the matrix. Global analysis on the conservation status of mammals shows a worrying scenario in relation to threats that these animals suffer. Forman and Alexander (1998) considered that collisions with vehicles have more impact than hunting to the mortality of terrestrial vertebrates, mostly in regions already disturbed.

Estimates of the number of killed animals do not provide useful information about the relationship between roads and wildlife, it is also important identify where animals are most likely to be killed (Ramp et al. 2005; Clevenger, Chruszcz, and Gunson 2003; Taylor and Goldingay 2010; Van der Ree et al. 2011). Specially in heterogeneous landscapes such those found in tropics, where land use and land cover patterns are diverse and unpredictable also because of road network expansion (Freitas, Hawbaker, and Metzger 2010), identifying the relationship between landscape and roadkill patterns is relevant to generate predictive models and management strategies to minimize the mortality rates of wildlife (Malo, Suárez, and Díez 2004; Taylor and Goldingay 2010).

This study aims to evaluate the spatial pattern of medium-sized mammal roadkills along two running years, on the SP-225 highway in the state of São Paulo, southeastern Brazil, taking into account the landscape characteristics in the highway surroundings. As the SP-225 is homogeneous in relation to road traffic, we expect that a higher frequency of roadkills may be explained by the species movement within the landscape, including the differences on permeability of areas along the road. This permeability is species specific, so the matrix more permeable to a forest species may not be the same for a species adapted to more open areas.

**METHODS**

**Study Area**

The study area is a stretch of SP-225 highway, from the Km 75 to Km 235, between the cities of Itirapina (22°15'10"S; 47°49'22"W) and Jaú (22°17'47"S; 48°33'28"W), northeast of State of São Paulo, Brazil (Figure 1). The climate has two distinct seasons: the rainy season from October to March and the dry season from April to September (Carvalho, De Marco Jr., and Ferreira 2009; Durigan, Siqueira, and Franco 2007). The predominant vegetation is cerrado (the Brazilian Savanna), semideciduous forest and riparian vegetation (Carvalho, De Marco Jr., and Ferreira 2009; Durigan, Siqueira, and Franco 2007). Three protected areas surround this road: Experimental Station of Itirapina, Experiment Station of Jaú and the Ecological Station of Itirapina. The Ecological Station of Itirapina is a native area of cerrado with several
endemic and threatened species (IUCN 2010), such as the birds *Nothura minor* (Spix, 1825), *Rhea americana* (Linnaeus, 1758), *Sicalis flaveola* (Linnaeus, 1766), *Cariama cristata* (Linnaeus, 1766), and the mammals *Chrysocyon brachyurus* (Illiger, 1815), *Ozotoceros bezoarticus* (Linnaeus, 1758) and *Speothos venaticus* (Lund, 1842).

The SP-225 highway was a two line, paved road, with roadside invaded by grasses. Parallel to the road, several varieties of crops are grown, mainly sugar cane fields, orange fields, *Pinus* sp. plantation, as well as pasture for cattle and some areas of native vegetation.

![Figure 1. Location of the SP-225 highway in State of São Paulo, showing the cities of Jaú and Itirapina, and the land use and land cover around highway (15 km).](image)

**Roadkill Data**

Data of mammal’s roadkills were collected daily, every three hours, by car at about 50-60 km/h fast, from January 2006 to February 2008. These data were collected in partnership with employees of the OHL Group Brazil. In each roadkill occurrence the following information was recorded: common name of the animal, location (km and geographic coordinates), date, time, and also picture of the killed animal was taken. Those photographs were archived and used to identify the animals.

**Analysis**

The frequency of roadkills of all mammal species and for each individual species was estimated. To evaluate the relationship between landscape and roadkills, three species were selected: the two more abundant, *Cerdocyon thous* and *Lepus europaeus*, and the threatened to extinction *Chrysocyon brachyurus* (IUCN 2010). *C. thous* is a generalist canid found in different physionomies of Cerrado and also in the Atlantic Forest, its home range area varies from 5 to
10 km² (Bueno and Motta-Junior 2004). *L. europaeus* is a non-native generalist herbivore, occurring mainly in open fields and pastures, usually between crops (Auricchio and Olmos 1999). Although *L. europaeus* is not considered a priority for conservation, we considered it relevant because it can be a prey for threatened species and attract them to the road verges increasing their road kill risks (Barrientos and Bolonio 2009). *C. brachyurus* is an omnivorous typical of open habitats such as grasslands and other open physionomies of Cerrado, its home range area varies from 21.7 to 115 km² (Carvalho and Vasconcellos 1995; Bueno and Motta-Junior 2006, 2004).

A map of land use and land cover was produced, featuring 15 km around the highway, to quantify landscape characteristics. The classification, with 87% of accuracy, was done based on a satellite image (CBERS 2, HRC sensor), manually using the ArcGIS 9.2 software with 4 meters of spatial resolution. The map had 7 classes: urban area, lakes and rivers, native vegetation, sugar cane fields, forestry (*Pinus* sp. plantation), pasture and orange fields. Native vegetation included cerrado, semideciduous and riparian forests because the species chosen have no preference for either habitat to displacement.

Around each occurrence, buffers of 1 km, 5 km and 10 km were generated and landscape characteristics, percentage of use and land cover, were measured within each buffer. According to Ramp et al. (2005) the buffer distances should be based on the ecology and behavior of the particular species. So, based on the estimate home range size of the species studied, three buffer sizes were considered to evaluate the effect of spatial scale on roadkill occurrence for each species. The same number of occurrence was used for randomly select absence points along the highway. Thus, for each species, there were roadkill occurrences and the same number of roadkill absences, where the same buffers and landscape measures were made.

To explain the occurrence of roadkills (presence/absence) through landscape characteristics, a logistic regression model was used for each species (dependent variable). The relative area (%) of each class of land use in each scale (1, 5 and 10 km) was used as independent variables. It was used a combination of at most two independent variables due to limitation in the sample size. Different scales have never been used in the same model. The best fitted model was obtained by the likelihood with binomial distribution package using Generalized Linear Models (GLM) in R 2.7.1 (2008 The R Foundation for Statistical Computing). The model selection was done by the Akaike's Information Criterion (Burnham and Anderson 2002) with correction for small samples (AICc), according to Hurvich and Tsai (1989). To sort the best models and evaluate their performance, we use the AIC weight (wi) and evidence (wi_max / wi_i, Burnham and Anderson 2002). It was performed all combinations of two variables using the Spearman correlation to avoid problems related to multicollinearity. Independent variables with correlation greater than 60% were not included in the same model (Zar 1996).

**RESULTS**

From January 2006 to February 2008, 114 mammals of 15 species were killed by vehicle collision in the SP-225 highway, between Km 75-235 (Table 1) which gives 35.6 mammals/100 km/year. The most killed by vehicles species was *Cerdocyon thous* (Table 1).

In the analysis of the relationship between landscape characteristics and roadkills, the best model showed that accidents involving *C. brachyurus* are more common where there is more urban and less pasture areas; the incidence of roadkill of *C. thous* was higher in areas where there is more forestry (*Pinus* sp.); and the higher number of roadkill of *L. europaeus* occurred where there is more forestry areas and more orange’s crops (Table 2). Sites with more *Pinus* plantation and less urbanization are also relevant to explain occurrence of *C. thous* roadkills, whereas sites with more forestry and less native vegetation also explained the occurrence of *L. europaeus* roadkills (Table 2). The models including buffer size as independent variable were not selected by AICc.
Table 1. Mammals hit on road SP-225, state of São Paulo, Brazil and the frequency of roadkills for each species during about two-year study.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerdocyon thous</td>
<td>Crab eating fox</td>
<td>32 (28.07%)</td>
</tr>
<tr>
<td>Lepus europaeus</td>
<td>European brown hare</td>
<td>22 (19.30%)</td>
</tr>
<tr>
<td>Hydrochoerus hydrochaeris</td>
<td>Capybara</td>
<td>10 (8.77%)</td>
</tr>
<tr>
<td>Chrysocyon brachyurus</td>
<td>Maned wolf</td>
<td>10 (8.77%)</td>
</tr>
<tr>
<td>Mazama gouazoubira</td>
<td>Brocket deer</td>
<td>8 (7.02%)</td>
</tr>
<tr>
<td>Euphractus sexcinctus</td>
<td>Sex-banded armadillo</td>
<td>7 (6.14%)</td>
</tr>
<tr>
<td>Dasypus novemcinctus</td>
<td>Nine-banded armadillo</td>
<td>6 (5.26%)</td>
</tr>
<tr>
<td>Tamandua tetradactyla</td>
<td>Lesser anteater</td>
<td>5 (4.39%)</td>
</tr>
<tr>
<td>Procyon cancrivorus</td>
<td>Raccoon</td>
<td>4 (3.51%)</td>
</tr>
<tr>
<td>Puma concolor</td>
<td>Puma</td>
<td>4 (3.51%)</td>
</tr>
<tr>
<td>Nasua nasua</td>
<td>Coati</td>
<td>2 (1.75%)</td>
</tr>
<tr>
<td>Galictus cuja</td>
<td>Ferret</td>
<td>1 (0.88%)</td>
</tr>
<tr>
<td>Leopardus pardalis</td>
<td>Ocelot</td>
<td>1 (0.88%)</td>
</tr>
<tr>
<td>Coendou sp.</td>
<td>Porcupine</td>
<td>1 (0.88%)</td>
</tr>
<tr>
<td>Cuniculus paca</td>
<td>Paca</td>
<td>1 (0.88%)</td>
</tr>
</tbody>
</table>

Table 2. Regression models selected by AICc (Evidence ≤ 2) for roadkill occurrence of three species: *Chrysocyon brachyurus* (n=10), *Cerdocyon thous* (n=32) and *Lepus europaeus* (n=22).

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Independent variables</th>
<th>AICc</th>
<th>wAIC</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. brachyurus</td>
<td>- pasture</td>
<td>60.94</td>
<td>0.970</td>
<td>1.0*</td>
</tr>
<tr>
<td></td>
<td>+ urban</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. thous</td>
<td>+ forestry</td>
<td>258.25</td>
<td>0.272</td>
<td>1.0*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- urban</td>
<td>258.90</td>
<td>0.197</td>
<td>1.4</td>
</tr>
<tr>
<td>L. europaeus</td>
<td>+ forestry</td>
<td>177.69</td>
<td>0.361</td>
<td>1.0*</td>
</tr>
<tr>
<td></td>
<td>+ orange</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- native vegetation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* best model selected by AICc
DISCUSSION

The number of 114 roadkills in a two-year study, or 35.6 mammals/100 km/year, could be considered lower than the average (106.6 ±113.5 mammals/100 km/year) for a region of Cerrado. Other studies done in Cerrado found from 300 mammals (1.59 mammals/100 km/year) (Cáceres et al. 2010) to 48 mammals (249.7 mammals/100 km/year) (Prado, Ferreira, and Guimarães 2006). The first was a 7 years study monitoring 2,700 km (Cáceres et al. 2010), whereas the second was a 1 year study monitoring 19.2 km (Prado, Ferreira, and Guimarães 2006). The nearest estimative from the average was an almost two-years study monitoring 216 km, which found 81.5 mammals/100 km/year (264 mammals killed) (Cunha, Moreira, and Silva 2010). It is very difficult to compare roadkill abundances between such different study efforts, however richness did not change so much (16 ±3.1 species) and the most killed species was *Cerdocyon thous* in 4 of 5 studies (Cunha, Moreira, and Silva 2010; Melo and Santos-Filho 2007; Cáceres et al. 2010; Prado, Ferreira, and Guimarães 2006; Vieira 1996). Some of those studies (Cunha, Moreira, and Silva 2010; Prado, Ferreira, and Guimarães 2006; Cáceres et al. 2010) found a vulnerable species (IUCN 2010) killed by vehicles, *Myrmecophaga tridactyla* (Linnaeus, 1758), maybe because they were done in more remote areas with lower traffic volume and road density (Van der Ree et al. 2011; Jaarsma, Van Langevelde, and Botma 2006; Alexander, Waters, and Paquet 2005; Van Langevelde and Jaarsma 2004; Goosem 2007).

Despite the hundreds roadkills found, most of those roadkills were constituted by common, abundant and wide distributed species. The 114 records of mammals shows that the animals most hitted (*Cerdocyon thous* and *Lepus europaeus*) by vehicles are those who normally have biggest population density, usually habitat generalists, locally abundant and those who are highly mobile (Forman et al. 2003; Coelho, Kindel, and Coelho 2008; Ford and Fahrig 2007; Barthelmess and Brooks 2010). As expected, the most usually hitten species in Cerrado, *C. thous* (Cunha, Moreira, and Silva 2010) whereas the second was a 1 year study monitoring 19.2 km (Prado, Ferreira, and Guimarães 2006). The nearest roadkills was higher in places with more forestry and less urban areas. Being an ecologically plastic animal, the *C. thous* can adapt well to agricultural and forestry areas, deforestation and regeneration (Juarez and Marinho-Filho 2002; Ferraz et al. 2010; Lyra-Jorge, Ciocheti, and Pivello 2008). Thus, the *C. thous* may be using forestry areas such as route of travel, because this areas are permeable to generalists species (Lyra-Jorge, Ciocheti, and Pivello 2008). However, *C. thous* avoid urban areas, maybe due to interference competition to *Canis lupus familiaris* or other canids (Di Bitetti et al. 2009; Vanak and Gompper 2010; Mitchell and Banks 2005). Vehicle collision of *Lepus europaeus* occurred in areas of forestry and orange crops and with less native vegetation. *L. europaeus* can be benefit greatly from the expansion of agricultural areas and is often found in open areas and crops (Auricchio and Olmos 1999). Probably hares are abundant in study site because in Europe hares avoid roads (Roedenbeck and Vos 2008). An exotic and well adapted species, *L. europaeus* could be a problem to crops and to other herbivores, as *Mazama gouazoubira* (Kufner et al. 2008).

Defining landscape characteristics related to road kill records provide a general clue to select where mitigation measure should be implemented (Gunson, Mountrakis, and Quackenbush 2011). However, even with low road-kill records, some species may be threatened by deaths on the roads, but the small sampling did not allow a landscape analysis as done for the more abundant species. For example, *Puma concolor* is included in red lists (IUCN 2010) and have low reproductive rates, thus needs measures to reduce road kill and improve landscape connectivity. It is important to note that *P. concolor* is usually found dead on Cerrado roads (Miotto et al. in press; Cáceres et al. 2010).
In those cases, we suggest the use of a ranking index considering presence of endangered species, as \textit{P. concolor}, and richness and road kill rates of target species, which gives a weight for those less abundant but relevant species (Bager and Rosa 2010).

The most suitable mitigation measure is another difficult task in tropics because there is a high species diversity and a low budget and yet not enough interest in this kind of conservation action. We believe that a more suitable solution to South America is a multi-species approach implementing road kill mitigation measures suitable to many species, as used in Australia (Laurance et al. 2009; Taylor and Goldingay 2010), instead mitigation measures designed for one or a few species, as used in Europe and North America (Huijser et al. 2009; Grilo, Bissonette, and Santos-Reis 2008; Mata et al. 2008; Cuperus et al. 1999). A possible way to convince government and businessmen, including from insurance companies, to invest in road kill is quantify human causalities and material damages caused by wildlife-vehicle collisions (Huijser et al. 2009). In South America, most mammals are not so big than north-American ones but we can use the larger ones, e.g. \textit{C. brachyurus} and \textit{P. concolor}, as flag species for implement road kill mitigation measures. Adapt culverts to be used as fauna underpasses could be another cheaper way to increase connectivity and reduce road kill for many species in tropics (Laurance, Gooses, and Laurance 2009; Grilo, Bissonette, and Santos-Reis 2008; Ascensão and Mira 2007). The lack of landscape planning in tropics also increases the risk of wildlife passages became obsolete in a near future because the species habitat does not exist anymore. That is another advantage to adapt culverts because they are used to water drainage too. However, in the case of protected areas cut by highways and dirt roads, mitigation measures should be applied to increase connectivity and reduce mortality on roads (Laurance, Gooses, and Laurance 2009). Road removal could be an option to be considered for protected areas (Switalski et al. 2004). Effects of roads on wildlife should be considered in strategies for define new protected areas, maybe using roadless areas as priority (Blake et al. 2008; Turner 2006; Strittholt and Deltasala 2001).

**CONCLUSIONS**

Many medium-sized mammals could be threatened by roads in Brazilian Cerrado. Most of them are common, abundant and wide distributed species as \textit{Cerdocyon thous}. However, many species killed by vehicles collision are included in red lists presenting some conservation concern, such as \textit{Chrysocyon brachyurus} and \textit{Puma concolor}. Understanding landscape patterns related to road kill records is a tool to define where and which mitigation measure is suitable and gives more information about species’ habitat use and movement routes. Species, as \textit{C. brachyurus}, may be vulnerable to road mortality because do not avoid roads, have a low reproductive rate and high dispersal capacity. We suggest a multi-species approach to design mitigation measures and to calculate human causalities and material damages related to wildlife-vehicles collisions to increase financial support to implement and keep mitigation measures.

**ACKNOWLEDGEMENTS**

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REFERENCES


USE OF UNDERPASSES BY MOOSE IN 2009 AND 2010 ALONG HIGHWAY 175 IN QUEBEC, CANADA: BOX CULVERTS WITH NATURAL FLOOR CAN BE A COST-EFFECTIVE PASSAGEWAY

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ABSTRACT

Moose-vehicle collisions can be particularly hazardous to motorists given the moose heavy weight and high center of gravity. Faced with an average per year of above 50 MVCs along 200 km of roadway in the Laurentides Wildlife Reserve, the Quebec Ministry of Transportation proceeded to fence 68 km while upgrading this roadway from a 2-lane to a 4-lane, divided highway. The QMOT also incorporated 4 crossing structures for moose and other large mammals to maintain connectivity and alleviate the barrier and the potential end effects of fences. A box culvert in which fences, entrances and inside floor were also designed to funnel and attract small to medium-sized mammals was also available for monitoring moose crossings. All 5 underpasses have been accessible to moose and other wildlife since late 2008 except for one more structure not yet completed.

As costs of building new structures increase, the QMOT needed to determine what would be the most the cost-effective underpass for moose in future transportation projects. We monitored and compared use by moose to determine structural and location features that would improve our future selection and design of underpasses for moose in other critical areas. We used 16 remote cameras from mid-May to late-October in 2009 and 2010. For each underpass, 2 cameras were installed to monitor moose activity at both entrances for each available pathway.

A minimum of 133 moose in 92 distinctive events successfully crossed the underpasses in 2009 compared to 253 moose in 209 events in 2010. Moose use of underpasses in 2009 might have been underestimated due to low trigger speeds in some of the used cameras. In 2010, the moose daily crossing rate reached 0.63 and 0.51 in the most heavily used underpasses. Adult cows counted for 45%, adult males 24%, calves 9% and unknown sex or age 22%. Use of the passages in 2010 peaked at 5h00 and between 20h00 and 22h00 at night. However 87% of all successful passages were at night, between 17h00 and 8h00. In 2010, we recorded 80% of all crossing events (167/209) in two underpasses. These passageways were located in high moose density areas. Openness ratio did not seem to have an effect on the moose use of the underpasses because one of two most used underpasses has an openness of only 0.9 compared to 14.15 for one of the other underpasses. The former, a box culvert with natural floor, had 115 moose crossing the structure compared to 93 moose for a bridge under open span in 2010. In one site, we believed that lack of shrubs and trees in the approach made the underpass less attractive from moose coming from the opposite direction.

Underpasses work very well for moose in our study area and this species might not need overpasses to move across highways as originally suggested from earlier studies in the Canadian Rockies. Located in small river or stream valleys, small underpasses made out of box culvert will be readily used by this non-gregarious and large ungulate species when properly funnelled with wildlife fences.

INTRODUCTION

Vehicle collisions with ungulates has been increasing in North America and Europe causing increasing number of human injuries and deaths, as well as considerable material damage (Forman et al., 2003). Moose-vehicle collisions (MCVs) are a serious problem and a particularly dangerous one as the impacting animal can weigh between 360 and 600 kg (794 to 1,323 pounds). For example, between 2000 and 2004 on a 193 km one-lane highway located north of Québec City, moose accounted for 99% of all vehicle collisions causing human injuries and of those, 17% caused severe injuries or were fatal for motorists (Quebec Ministry of Transportation, unpublished data).
Given the high probabilities of injuries and human deaths in MCVs, Quebec Ministry of Transportation (QMOT) have erected between 2007 and 2010 over 111.4 km of 2.4 m high metallic fences in 4 different road sections to prevent moose from crossing HWY 175. To maintain connectivity and reduce the barrier effects of fencing for this highly mobile animal and other wildlife, a number of crossing underpasses were designed and built to allow movements across the highway.

In this paper we share information and preliminary results related to the design and use of underpasses by North American moose following the construction and the protection of nearly 55.7 km of highway sections with wildlife fencing. The main objectives were (1) to present the design and structural characteristics of underpasses for moose planned and built along with wildlife fencing and (2) provide preliminary data on the effectiveness of underpasses and fencing for moose.

**STUDY AREA**

Our monitoring study was implemented in the context of an upgrading project from a 2-lane roadway of 144 km to a 4-lane divided highway started in 2005 and completed in 2010. The roadway build in the early 50’s bisected the study area east to west for a length of 144 km. The average traffic volume in 2000 was between 4,800 and 3,300 vehicles per day at the entrance and exit of the Laurentides Wildlife Reserve (LWR). The summer average traffic volume varies between 6,300 and 4,600 vehicles per day. A very light increase in average traffic volume was documented in 2010.

This transportation project was located in a wide forested area in which moose is the dominant species of ungulates and a special concern for road and safety managers. It took place in the Laurentides Mountains located 35 km (22 mi) north of Quebec City, in south-central Quebec (Fig. 1). The study area covers approximately 9000 km$^2$ (3475 mi$^2$) and comprises mountain and rolling landscapes with numerous lakes, two provincial parks (De la Jacques-Cartier, Des Grands Jardins) and the LWR. The altitudinal range varied between 163 and 859 m ASL. Snow precipitations occur between October and May and total on average 593 cm. The LWR is among areas of the world with the highest annual snowfalls. The annual mean temperature varies between 14.8°C and -15.3°C.

![Fig. 1: Location of the study area and HWY 175, Province of Québec, Canada](image_url)
The central part of the study area is located at higher elevation and the vegetation is largely dominated by pure coniferous stands of black spruce (Picea mariana) and balsam fir (Abies balsamea). The southern and the northern part are largely composed of mixed stands of balsam fir and white birch (Betula papyrifera) or trembling aspen (Populus tremuloides). Forests located with the LWR are currently harvested for paper and lumber production, affecting approximately 37 km$^2$ per year. Spruce budworm outbreaks have also had significant effects on maintaining young forested stands over the past 50 years.

Wolf and black bears are the other big game species present in the area. White-tailed deer occurs only in limited numbers in the most northern and southern part of the study area. A small population of woodland caribou is also present but their use of the area has been mostly limited to the eastern part of the study area. Moose and black bear hunting are strictly controlled and light in the LWR so that natural regulation is probably in effect. Human development is limited to few hunting and fishing cabins provincially owned and used only between May and October and cross-country skiing trails and winter cabins.

The last aerial inventory of moose in LWR (2009) revealed a mean density estimate of 4.1 moose/10 km$^2$ ± 12%($\alpha=0.10$), with density reaching over 10 moose/10 km$^2$ in the best habitats located in the northern and southern parts of the study area. The total moose population was estimated at 3,283 individual (MRNF, 2010). Because moose density has almost doubled over the past 15 years, risks of moose-vehicle collision have also increased along HWY 175.

**HIGHWAY PROJECT DESCRIPTION**

The upgrading project of HWY 175 began in 2005 and aimed at improving safety for users connecting between Cities of Saguenay and Québec. The upgrading project has been split in many road sections and construction contracts of about 7 to 10 km long. Road construction started from both the northern and southern ends. The first construction work started in 2005 and the last one was almost completed in spring 2011. The project included extensive mitigation measures to reduce moose-vehicle collisions. It included a total of 66.2 km of road protected with wildlife fencing (2.4 m high metallic fences) in 4 distinct stretches, over 25 emergency exits to release moose that may access the highway from the edges of fencing or left open gates, over fifteen Texas gates and 5 underpasses for moose (3 open-span bridge extensions and one concrete box culvert). All bridges and the box culvert were new structures built. Not designed as a moose underpass, two concrete box culverts (an existing one and a new one) were readily used after wildlife fencing was erected in the vicinity.

The cross section of the 4-lane divided highway consists of separate 2-lane sections consisting of two 3.7-m lanes, two 3-m outside shoulders and around 15 m of adjacent rights-of-way (sensu roadsides). The 2-lane sections are separated by a grass median of 20 m (66’) and the total right-of-way width varies between 90 to 105 m (344’).

**METHODS**

We documented use of underpasses with 2 to 4 digital infrared cameras installed at each site to cover the entire width and to be able to gather data on successful and unsuccessful attempts. In 2009 we used both the Moultrie Model 4.0 Digital Game Camera and the Reconyx. However due to their low trigger speed, Moultrie cameras were replaced early during the 2010 surveys in most cases by the Reconyx Model. We checked all cameras and collected memory cards every three weeks from mid-May to late October. The infrared cameras were in operation between 158 to 180 days each year. To prevent double-counting of moose all cameras were set at the same time and a date and time stamp appeared on each photo. No attempts were made to identify individual moose that might be repeat users of the underpasses given the difficulty of distinguishing a cow from another one in particular.

Before highway construction started in each road section we conducted monthly track counts from May to October along the roadway. We waited a minimum of 2 days after strong showers and thunderstorms to allow moose to move and make tracks. Such weather events tend to improve the quality of the shoulder substrate for reading tracks and erasing old tracks. Track counts were conducted by bicycle simultaneously on both sides on the roadway. Each track was either considered to have crossed or to have paralleled the roadway. We used a GPS with a positional accuracy of 6 to 10 m to obtain coordinates of track locations.

**RESULTS**

**Dimensions and Description of Moose Crossing Structures**

All planned passageways for moose needed to be associated with required new structures over watercourses to reduce costs. As moose along HWY 175 are known to move in valleys and along rivers and streams during the summer
crossing structures were located along selected streams and rivers near or in road-crossing hotspots based on tracks surveys and analysis of moose-vehicle collisions location data. Table 1 provides technical information on crossing structures available in the fenced stretches of HWY 175. Moose-proof fencing was installed between kilometre markers 84 and 110, 175 and 180 and 190 and 214.

Table 1. Location and description of crossing structures on the upgraded HWY 175.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Kilometre marker</th>
<th>Type</th>
<th>Span (m)</th>
<th>Rise (m)</th>
<th>Length (m)</th>
<th>Openness ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bureau*</td>
<td>86.8</td>
<td>2 concrete box culverts</td>
<td>6 (19.7')</td>
<td>1.98 (6.5')</td>
<td>13 (42.6')</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6 (19.7')</td>
<td>2.83 (9.3')</td>
<td>13 (42.6')</td>
<td>1.31</td>
</tr>
<tr>
<td>Décharge du lac à Noël</td>
<td>94.6</td>
<td>2 open-span bridges</td>
<td>25 (82')</td>
<td>7.4 (24.1')</td>
<td>13 (42.6')</td>
<td>14.15</td>
</tr>
<tr>
<td>Tourangeau**</td>
<td>177.3</td>
<td>2 open-span bridges</td>
<td>25 (82')</td>
<td>5.0 (16.4')</td>
<td>16 (46.9')</td>
<td>7.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>each</td>
<td></td>
</tr>
<tr>
<td>Gilbert***</td>
<td>198.0</td>
<td>2 concrete box culverts</td>
<td>14.7 (48')</td>
<td>5.3 (17.4')</td>
<td>17.7 (58.0')</td>
<td>4.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>each</td>
<td></td>
</tr>
<tr>
<td>Cyriac</td>
<td>209.9</td>
<td>2 open-span bridges</td>
<td>38 (125')</td>
<td>4.9 (16.1')</td>
<td>13 (42.6')</td>
<td>14.32</td>
</tr>
</tbody>
</table>

* Not originally designed to be a moose underpass  
** Construction ended in 2009  
*** Only one pathway located south of the river

Use of Fenced Roadway Sections Before Construction

Our moose tracks surveys along the roadway in 2006 showed that 4.7 and 3.4 moose on average crossed the roadway daily in the southern and northern part respectively between late May and September. The peak of moose movements across the roadway occurred in May-June (Table 2). We estimated that over a 6-month period at least 857 and 613 moose would have crossed the roadway in either direction in the southern and northern parts respectively.

Table 2. Number of fresh moose tracks per day that crossed HWY 175 in monthly surveys conducted in 2006.

<table>
<thead>
<tr>
<th>Period of survey</th>
<th>Number of fresh moose tracks per km per day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Km 68 to 115</td>
</tr>
<tr>
<td></td>
<td>Km 179 to 221</td>
</tr>
<tr>
<td>Late-May</td>
<td>0.16</td>
</tr>
<tr>
<td>Mid-June</td>
<td>0.25</td>
</tr>
<tr>
<td>Early July</td>
<td>0.13</td>
</tr>
<tr>
<td>Late-July - early August</td>
<td>0.06</td>
</tr>
<tr>
<td>Late-August</td>
<td>0</td>
</tr>
<tr>
<td>Late-September</td>
<td>0.01</td>
</tr>
<tr>
<td>Mean</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
</tr>
</tbody>
</table>
Use of Crossing Structures By Moose After Construction

Construction of bridges and installation of box culverts were completed by the end of year 2008 except for the Tourangeau underpass. The associated wildlife fencing was also put up during the same period in road sections where underpasses were located. Digital infrared cameras were installed in spring 2009 and started to record moose use of the underpasses. A total of 186 moose successfully crossed the highway using the available 4 underpasses and the pair of adjacent small concrete box culverts over the Bureau stream not designed for it use by moose (Table 4). The most used underpass was the two open-span bridges over the Décharge du lac à Noël (Figure 2) located in the southern part of HWY 175. This underpass was used by more than one moose on average every other day in 2010. Surprisingly at least 33 moose used two box culvert with a maximum height of 1.98 m to cross the highway. Photos showed that moose either walked in the stream or on the small path (1m wide) along the walls while in the culvert and got on dry grounds as soon as they were out of it. In the northern part of the study area, the highest number of passages was recorded at the Cyriac underpass (Figure 3) with a total of 17 moose.

Table 3. Total number of moose passing through each underpass between early or mid-May to late October or early November on HWY 175.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Kilometre marker</th>
<th>Type</th>
<th>2009</th>
<th>2010</th>
<th>% change in nb of moose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nb of events</td>
<td>Nb of moose</td>
<td>Moose/day</td>
</tr>
<tr>
<td>Bureau*</td>
<td>86.8</td>
<td>2 concrete box culverts</td>
<td>24</td>
<td>33</td>
<td>0.23</td>
</tr>
<tr>
<td>Décharge du lac à Noël</td>
<td>94.6</td>
<td>2 open-span bridges</td>
<td>69</td>
<td>117</td>
<td>0.65</td>
</tr>
<tr>
<td>Tourangeau**</td>
<td>177.3</td>
<td>2 open-span bridges</td>
<td>3</td>
<td>6</td>
<td>0.033</td>
</tr>
<tr>
<td>Gilbert***</td>
<td>198.0</td>
<td>2 concrete box culverts</td>
<td>11</td>
<td>13</td>
<td>0.066</td>
</tr>
<tr>
<td>Cyriac</td>
<td>209.9</td>
<td>2 open-span bridges</td>
<td>16</td>
<td>17</td>
<td>0.087</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>123</td>
<td>186</td>
<td>1.07</td>
</tr>
</tbody>
</table>

* Not originally designed to be a moose underpass and monitored by only two cameras.
** Construction ended in 2009
*** Only one pathway located south of the river

In 2010 the use of underpasses along HWY 175 by moose increased on average by a 103% overall. At least 253 moose successful crossed the underpasses (Table 3). The most used underpass was the pair of small concrete box culverts over the Bureau Stream with a recorded 108 passages by moose (Figure 4). The recorded level of use of this underpass more than tripled over just one year. Its closest underpass showed a slight decrease but still remained often used by moose in 2010. In the north, the Tourangeau (Figure 5) and Gilbert underpasses (Figure 6) received more use by moose, more than triple the number recorded in 2009. The increase of moose passages in the Tourangeau underpass is not surprising because it was still under construction in 2009 when the monitoring started. Overall, 3 moose used the underpasses along HWY 175 every other day in 2010. Underpasses located in the southern part of HWY 175 were used more often than underpasses located in the northern part of HWY 175.
HWY were the most used by moose and accounted for 78 to 80% of all recorded passages. These values would have probably been higher if some construction operations would not have taken place nearby during few weeks. For all underpasses except for the Bureau culverts our cameras detected 5 approaches over 104 events (4.8%) in 2009 that did not result into a successful crossing by moose. In 2010 the ratio of approaches and unsuccessful crossings was 9 out of 126 events (7.1%). These values are probably underestimated because some of the cameras could not capture all unsuccessful crossings.

Fig. 2: Moose underpass at the Décharge du lac à Noël on HWY 175, Québec, Canada

Fig. 3: Moose underpass at Cyriac River, HWY 175, Québec, Canada

Fig. 4: Moose crossing the median between the Bureau concrete box culverts, HWY 175, Québec, Canada
Fig. 5: Moose underpass (one pathway) at the Tourangeau River, HWY 175, Québec, Canada

Fig. 6: Moose underpass at the Gilbert River, HWY 175, Québec, Canada

Sex and age of moose traveling across the underpasses could be determined in 78 % of the cases (Fig.7). Many moose were cows (presumably 1 to 2-years old) or cows with calves. They accounted for at least 69% of the underpasses users. The proportion of each sex and age group class did not differ from those recorded in the last moose survey of the Laurentides Wildlife Reserve conducted in 2009 (bulls:32%, cows:52%, calves: 16%, data from MRNF 2010, G-test, $G = 0.77$, df = 2, $p > 0.05$).

Fig. 7: Sex and age of detected moose using underpasses in 2010 (n = 253)
Movements of moose thru underpasses were not evenly distributed over a 24-hour. Moose traveling in underpasses occurred mainly between 19h00 and 08h00 (Figure 8). Peaks of moose movement happen at dawn around 05h00 and at dusk between 20h00 and 22h00.

DISCUSSION

The results of our monitoring study clearly indicated that North American moose can readily use underpasses to get across highway corridors when properly funnelled with wildlife fencing. In 2010, an average of 10 moose per week crossed the HWY 175 using 5 underpasses within three fenced sections. Although little data exists elsewhere on moose crossing rates because very few transportation projects integrate mitigation measures for moose, the passage rate is probably the highest rate ever recorded. It is slightly higher than the value of 8.4 moose per week recorded in Finland within 11 underpasses (Väre, 2002) and well above the level of use documented in Sweden by Sellé and Olsson (2009) for 26 underpasses. Contrary to earlier results obtained in Banff National Park (see Forman et al., 2003), moose showed no reluctance to use underpasses to cross the highway. Therefore designing and building underpasses can be a very cost-effective crossing structure for moose to increase motorist safety and habitat connectivity.

Such heavy use by moose and within a short time after the end of construction indicates that the structures were properly designed and located to suit moose needs while traveling across the LWR and the two provincial parks landscape. However moose crossing frequencies varied among underpasses and several determinants seemed to play a role in influencing passage rates. Moose density appears to be the most influential determinant of crossing rate recorded in our monitoring study. This has been documented in many species (see Clevenger and Waltho, 2003) and it has to be accounted for when comparing structural features and effectiveness.

Along HWY 175, the two most used underpasses (Ruisseau Bureau and Lac à Noël) are located in areas where moose density is the highest in the LWR, nearing 10 moose/10 km². The Gilbert underpass is also located in the center of an area with high moose density, thus increasing the probability of moose using it. In contrast, the two remaining crossing structures are situated in low moose density areas because of low quality habitat (Tourangeau) or heavy hunting pressure in neighboring landscape (Cyriac). These structures will be able eventually to accommodate population increases over the long term and become more effective. This is particularly the case for the Tourangeau underpass for which habitat quality in the surrounding landscape will greatly improve in the next 10 years following current forestry operations.

Proximity to forest cover at the entrances of the Bureau box culverts may have played a significant role in making these crossing structures very attractive for traveling to moose. The forest edge is located within 10 m of the entrances on both sides and there are well developed alder-willow thicket associations in the highway median. Forest edges are also located close (15 to 20m) to the entrances at the Cyriac and Gilbert underpasses (figures 3 and 6). Entrances to the lac à Noël crossing structure are located further (50 m) from forest edges but natural forest regeneration and extensive
tree and shrub plantations in the transition zone are progressively improving cover at the ends of the passage. With time, all crossing structures will have better suitable moose habitat or cover for movements on either side of the structures. The distance to the nearest cover seemed to play a certain role in facilitating crossing of underpasses by moose in Sweden (Seiler and Olsson, 2009).

Structural features did not appear to be an important determinant of a structure’s success for moose in our monitoring study. The smallest structures (Bureau crossing structures) had the smallest openness index (near 1.0) but the highest number of moose crossings in 2010. The crossing frequency was slightly above the one recorded at the Lac à Noël crossing structure which has an openness index of above 14. Previous studies on deer and other ungulates found that crossing structures needed to be wide and high to obtain a high crossing rate (Donaldson 2006, Clevenger and Waltho 2003, Foster and Humphrey 1995). Seiler and Olsson (2009) set at 2.3 the minimum openness ratio for a moose underpass. In our study, the Bureau and the lac à Noël crossing structures were both located along small valleys in an area with plenty of moose. High density of moose and high productivity level probably induce each year high degree of dispersal among sub-adults in the population. Those individuals might show less reluctance to go across these structures compared to mature cows and bulls. However, although large numbers of sub-adults use the crossing structures based on our photographs, cows with young calves were often seen crossing these structures despite their known shyness.

Moose use of box culverts and underpasses along HWY 175 contrasts with the suggestion that North American moose prefers overpasses to underpasses based on the monitoring of crossing structures along fenced sections of the Trans-Canada highway in Banff National Park, Alberta (Forman et al., 2003). Although our study did not provide the set-up for comparing effectiveness of underpasses and overpasses for moose, it showed that underpasses and small box culverts can be readily used by moose in the proper conditions (high moose density, entrances close to forest cover and located in valleys). It is likely that low density of moose in habitats along the Trans-Canada highway does not provide the best conditions for properly testing the preference for these major types of passageways for moose.

Long sections of moose-proof fences induce barrier effects to this largely mobile animal and changes in movement patterns as in other species like the white-tailed deer (McCollister and Van Manen, 2010). Crossing opportunities must therefore be provided to reduce wildlife-vehicle collisions associated with and close to fence ends (Clevenger et al. 2001). By comparing the preconstruction (2006) average daily rate of moose walking across the 2-lane roadway sections to be fenced and combined with underpasses to the daily average use of the 5 underpasses by moose in 2010, it would represent a gross figure of 33% of moose movements funnelled to these moose crossings. The use of underpasses by over 250 moose in 2010 from a potential population number of above 600 moose living within 5 km of the 144-km highway (4.4 moose/10 km² X 144 km X 10 km) provide clear evidence that connectivity has been maintained for a significant portion of the moose population while providing a safer highway for motorists. Contrary to results obtained by Olsson and Widen (2006) in Sweden, underpasses along HWY 175 were heavily used by moose after construction, therefore minimizing potential effects of the upgraded highway to moose accessibility to resources and dispersal rates.

A number of decisions were taken early at the planning and designing stages of these structures and their surrounding landscape to facilitate moose use of these underpasses even if some were not located in high density areas for moose, of large sizes or high openness indexes. We also learned from this project that small box culverts when properly located in moose habitats can provide very efficient crossing opportunities for moose. However, successful management actions implemented at one site may not give the same result in another area depending upon a variety of attributes. Also, small details in designing structures such as maintaining forest cover can make a difference to improve the efficiency of a crossing structure.

In conclusion, the five completed crossing structures combined with moose-proof fencing have been readily and successfully used by moose and have so far contributed to improving safety for motorists and maintaining moose movements between both sides of the highway by concentrating in underpasses.

ACKNOWLEDGEMENTS

The Ministère des Transports du Québec (QMOT), the Ministère des Ressources naturelles et de la Faune du Québec (QMNWR), the University du Québec à Rimouski and Aecom Consultants Inc. provided funding for this project as well as human and technical resources. We would like to extend our appreciation towards all wildlife specialists who helped us and still doing it all along. Christian Dussault (Québec Ministry of Natural Resources and Wildlife), Mathieu Leblond (Université du Québec à Rimouski), Jean-Pierre Ouellet (Université du Québec à Rimouski) and Héloïse Bastien (Québec Ministry of Natural Resources and Wildlife), provided important input into study feasibility and design.
BIOGRAPHICAL SKETCHES

Yves Leblanc is a senior wildlife research biologist with AECOM Consultant Inc. He is currently under contract with the Quebec Ministry of Transportation to assess and reduce moose and white-tailed deer vehicles collisions in different upgrading and new highway projects. Yves is also involved in many environmental impact assessment of major hydroelectric and road development on ungulates, waterfowl and fur bearing animals in northern Quebec. He has also been involved in wildlife management and research projects with the Quebec Ministry of Natural Resources and Wildlife on beaver, fisher and woodland caribou. Yves holds a B. Sc. in biology from Universite Laval and a M. Sc. in Zoology from the University of Alberta, Alberta.

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Yves Bédard is an environmental specialist at a regional office of the Quebec Ministry of Transportation. He is currently in charge of environmental issues with roadways. He was involved in the environmental impact assessment and monitoring studies of Highway 175. He holds a B. Sc. in Biology from Université de Montréal and a M. Sc. in Biology from Laval University.

Donald Martel is an environmental specialist at a regional office of the Quebec Ministry of Transportation. He is currently in charge of environmental issues. He was also involved in the environmental impact assessment and monitoring studies of Highway 175. He holds a B.S. in geomatics from Université Laval and is currently a member of the Quebec Corporation of land surveyors.

Éric Alain is a wildlife technician at a regional office of the Quebec Ministry of Transportation. He is currently monitoring wildlife crossings and fish passages along HWY 175 and providing infield support on environmental issues for road contractors and engineering firms.

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WILDLIFE FENCING RESEARCH FOR I-90 SNOQUALMIE PASS EAST:
NOT JUST AN ANIMAL COMMITMENT

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ABSTRACT

The use of exclusionary fencing is not a new practice. Exclusionary fencing has been tested and used across the nation to keep wildlife off of state highways to minimize wildlife / vehicle collisions. For the Washington State Department of Transportation’s I-90 Snoqualmie Pass East project, meeting exclusionary fencing goals was challenged by the high-altitude project area’s extreme weather conditions. Not only did the project team need to find a suitable fence design that excluded wildlife, but also one that would withstand 140 inches (or more) of snow and rain each winter, require low maintenance and costs, and look aesthetically pleasing.

To find a fence design that would meet all these requirements, the design team embarked on a three-year wildlife exclusionary test fence performance study. During the fall of 2007, 2008, and 2009, the team constructed (and repaired) test fences with many different types and combinations of materials. The design team initially examined three fence types – metal posts and chain link fabric (Alaskan Moose Fence), wood posts and eight-foot fabric (Canadian Wildlife Fence), and wood posts and two rows of four-foot fabric (WSDOT Fence). Each test fence was approximately 300 feet long and placed within 30 feet from the edge of the highway pavement.

The teams’ primary study objective was to assess how well each fence component held up to the harsh weather conditions of the pass, including direct impact from snow thrown from passing snowplows. The design team inspected each fence in the spring, after the snow melted.

After assessing performance in the spring of 2008, the team added two additional modified fence designs and eliminated two of the original designs. The three remaining modified fences were:

- Fence C: Canada Wildlife Fence (Modified)
- Fence D: Combination Steel Pipe and Cable Fence
- Fence E: Combination Steel “C-post” and ElectroBraid® Fence

After three years of study, the design team determined that all three remaining fence designs could withstand the harsh environment of Snoqualmie Pass with varying degrees of repair issues and design modifications. Fence C showed the fewest component failures and did not appear to need significant modifications. Fence D suffered from a significant number of fabric-to-post wire tie failures. Fence E suffered from shearing of the fabric-to-post bolts on most of the posts, but simple modifications would eliminate downward translation of the fabric.

The team worked with fence contractors and WSDOT maintenance personnel to develop a final recommendation package. The group evaluated how well fence materials and construction methods held up during each year’s evaluation period. The team also considered construction, maintenance requirements, and costs. The design team then selected the final fence design based off of the recommendation package, physical engineering and practical performance, and aesthetics that fit into the overall landscape architecture “theme” for the project. Most importantly, the final fence design was selected to ensure WSDOT’s investments promote safety for the traveling public and wildlife.

INTRODUCTION

The Washington State Department of Transportation’s (WSDOT) I-90 Snoqualmie Pass East Project (I-90 Project) is a 15-mile highway improvement project that will ensure the continued availability of Interstate 90 as a primary east-west statewide corridor. Through the I-90 Project, WSDOT will improve the safety and reliability of this corridor by reducing avalanche risks to the traveling public, minimizing road closures required for avalanche control work, and reducing the risk of rock and debris falling onto the interstate from unstable slopes. WSDOT will also fix structural deficiencies and
provide for the recent and predicted increases in traffic volume. Ecological connectivity is another important project component. WSDOT will work to reduce wildlife / vehicle collisions by re-connecting habitat across I-90 and improving mobility of aquatic species and wildlife.

Plans for the project include widening the existing four lane interstate to six lanes, replacing deteriorated concrete pavement, straightening sharp roadway curves, stabilizing unstable rock slopes, building a new, more efficient snowshed (a concrete shed covering the roadway to provide permanent protection from avalanches and other falling debris to travelers passing through Snoqualmie Pass), and constructing wildlife crossings structures.

The first five miles of the I-90 Project from Hyak to Keechelus Dam received funding in 2005 from the Washington State Legislature through the Transportation Partnership Account – a 9.5 cent increase in the gas tax. Total current funding is $541 million. The remaining 10 project miles from Keechelus Dam to Easton remain unfunded.

WSDOT started construction on the I-90 Project in the spring of 2009. The project, due to its complexity, is divided into several construction contracts. The three main construction contracts are Phase 1A, 1B, and 1C. These contracts include the physical reconstruction of the highway from Hyak to Keechelus Dam. Construction is scheduled for completion by 2016. Several smaller contracts also exist for stormwater retrofitting, vegetation management, and wildlife exclusion fencing installation.

For the wildlife fencing contract, the design team continues to overcome challenging obstacles in meeting wildlife exclusionary goals for the I-90 Project. While the use of exclusionary fencing is not a new practice to keep wildlife off of state highways and minimize wildlife / vehicle collisions, WSDOT needed to find a suitable fence design for this high-altitude project (elevation 3,022 feet) that could withstand 140 inches (or more) of snow and rain each winter, require low maintenance and costs, and look aesthetically pleasing.

To find a fence design that would meet all these requirements, the WSDOT I-90 Project design team embarked on a three-year wildlife exclusionary test fence performance study during the fall of 2007, 2008, and 2009. The team constructed (and repaired) test fences with many different types and combinations of materials. The teams’ primary study objective was to assess how well each fence component held up to the harsh weather conditions of the pass, including direct impact from snow thrown from passing snowplows. Most importantly, the fence design needed to ensure that WSDOT’s investments promote safety for both the traveling public and wildlife.

Before diving into the wildlife fencing study’s goals, objectives, methods, observations, and results, it’s important to first understand the I-90 Project area and physical constraints.

UNDERSTANDING THE I-90 PROJECT AREA

I-90 spans 300 miles in Washington State from the Port of Seattle to the Idaho state line, and then continues east across the United States to Boston, MA. I-90 is the major east-west transportation corridor across Washington and is vital to the state’s economy (see figure 1) (WSDOT 2008).

The I-90 Project improves a 15-mile portion of I-90, beginning on the eastern side of Snoqualmie Pass at milepost 55.1, just east of the Hyak Interchange, where the existing highway narrows from six lanes to four lanes. The project end point is at milepost 70.3 at the West Easton Interchange, where the terrain becomes flatter and the highway is straighter. This 15-mile stretch of I-90 is in Kittitas County, WA, and is predominately located on federal land within the Okanogan-Wenatchee National Forest.

The project corridor is located along a high mountain pass in the Central Cascades. The general topography is one of mountainous peaks and valleys. For the first six miles of the project area, I-90 runs along a narrow corridor between the shores of Keechelus Lake, a deep-water agricultural reservoir, and steep mountain slopes. These steep mountain slopes contain volcanic bedrock at varying depths that are subject to deep fissures and stress cracks with weakened slip planes, which when combined with high annual precipitation and freeze-thaw conditions, makes them susceptible to landslides, debris flow, and avalanches.
I-90 is built primarily within an easement on National Forest land. The large areas of protected state, federal, and conservation lands north and south of I-90 support a broad range of habitats and a diverse array of plants and wildlife. Since the late 1990s, the area has been managed according to the Snoqualmie Pass Adaptive Management Area Plan. This plan requires protection of old-growth habitat, removal of portions of existing Forest Service roads, and management of recreation to facilitate species movement. In recent years, there have been substantial private and public land conservation efforts to protect old-growth forest, provide larger contiguous blocks of forested habitat, and facilitate habitat connectivity across the I-90 corridor through the acquisition of private land. The Cascades Conservation Partnership, the Mountains-to-Sound Greenway Trust, the U.S. Fish and Wildlife Service (USFWS), and the U.S. Forest Service (USFS) have invested over $100 million in these efforts during the last five years. These land purchases, along with the I-90 Land Exchange, have added 75,000 acres (approximately 117 square miles) of land to the National Forest system adjacent to and within the I-90 Project area (MDT 2006).

Even with conservation efforts, I-90’s presence limits wildlife movement and forms a physical barrier between upstream and downstream aquatic environments. Existing culverts and narrow bridges limit aquatic species movement, and in many cases, the highway embankment has filled in habitat that once made up channels, floodplains, and associated wetlands (WSDOT 2008). Adequate connections between habitats and hydrologic features on either side of I-90 are necessary for the continued health of the project area’s diverse ecosystems.

The last major road construction on I-90 Snoqualmie Pass began in the 1950s when President Dwight D. Eisenhower signed the Federal-Aid Highway Act of 1956, which started the construction of Interstate Highways; construction was completed in the 1970s. Since the 1970s, the state’s transportation needs for I-90 over Snoqualmie Pass have changed, and the existing roadway has deteriorated.

Today, daily traffic on Snoqualmie Pass averages about 27,000 vehicles, typically 22,400 passenger vehicles and 4,600 freight vehicles. Traffic volumes can rise to more than 60,000 vehicles on weekends and holidays. According to WSDOT traffic studies, travel across Snoqualmie Pass is growing at an annual rate of 2.1 percent, with 51,000 vehicles projected to use I-90 daily by 2028.
IDENTIFYING A PROJECT PURPOSE AND NEED

Seeing a need for additional highway capacity and safety improvements, WSDOT began the public scoping process for the I-90 Project in 1999. By 2000, an Interdisciplinary Team (IDT) was formed consisting of representatives from WSDOT, the Federal Highways Administration (FHWA), USFS, Environmental Protection Agency (EPA), USFWS, and Washington Department of Fish and Wildlife (WDFW); advisory agencies included Washington State Parks, U.S. Army Corps of Engineers, and Washington Department of Ecology (Ecology). The IDT was formed to begin preliminary engineering and environmental analysis of the project area. Additional teams were formed, including a Mitigation Development Team consisting of biologists and hydrologists from WSDOT, USFS, USFWS, and WDFW, and a Wetlands Mitigation Technical Committee consisting of a GIS specialist, biologist, and environmental planner, to conduct further environmental analyses and provide design recommendations.

After five years of corridor analysis, WSDOT published the I-90 Snoqualmie Pass East Project Draft Environmental Impact Statement (Draft EIS) for public review and comment in 2005. The Draft EIS highlighted six build alternatives that could potentially meet the project’s identified purpose and need for:

- Reducing the risks of avalanche to the traveling public and eliminating road closures required for avalanche control work,
- Reducing the risk of rock and debris falling onto the roadway from unstable slopes,
- Fixing roadway structural deficiencies by replacing damaged pavement,
- Providing for the growth-related increases in traffic volume, and
- Connecting habitat across I-90 for fish and wildlife (WSDOT 2005).

Over the next two years, WSDOT continued using existing partnerships and formed new teams, including a Stormwater Technical Committee and Wildlife Monitoring Technical Committee, to help advance technical investigations and identify a preferred design alternative for the I-90 Project. These collaborative efforts culminated with the release of the Final EIS in August 2008 that identified WSDOT’s preferred design alternative for the I-90 Project. FHWA issued its Record of Decision concurring with WSDOT’s preferred alternative in October 2008, which paved the way to complete final design and for construction to begin. The I-90 Project Preferred Alternative not only addresses transportation issues, but also the ecological connectivity needs of the corridor. Ecological connectivity is listed in the project’s purpose and need statement, a first for a WSDOT project.

WILDLIFE FENCING STUDY

Ecological connectivity objectives, specifically wildlife connectivity, focus on improving motorists’ safety by reducing wildlife / vehicle collisions and improving the ecological permeability of the highway for fish and wildlife. To ensure the success of ecological connectivity investments, such as wildlife bridges and culverts, incorporation of wildlife exclusionary fencing is required. But, due to the project area’s extreme climatic conditions and topography, a standard fence design would not meet project objectives. WSDOT had to search for a fence design that would withstand 140 inches (or more) of snow and rain each winter, require low maintenance and costs, and look aesthetically pleasing.

To identify a suitable exclusionary fence design, the I-90 Project team (consisting of WSDOT engineers, consultants, and environmental staff) embarked on a three-year wildlife exclusionary test fence performance study from the fall of 2007 to spring 2010. The teams’ primary study objective was to assess how a variety of fence components held up to the harsh weather conditions of the pass, including direct impact from snow thrown from passing snowplows. The fence study did not focus on the exclusionary performance of the fence designs, but rather, durability and maintenance issues. Study criteria for the evaluation study included monitoring damage to or pullout of the connectors between the fencing and the post; stretching of the wire fencing, resulting in loss of tautness or wire breakage; wire corrosion that could result in breaking of the wire; excessive movement (rotation or translation) or pullout of the posts; and wood rot or metal corrosion that could result in bending or breaking of the posts (URS 2007).

For the study, the team first selected a location for the test fences that represented the worst-case conditions for the future planned permanent fences with respect to snow load during the winter (see Figure 2). The location was deliberately selected to be where extreme snow plow activities would occur during the winter, with unusually high dynamic loads from plowed snow and static loads from accumulated snow (URS 2010). These snow loads would be relatively large because the snow in this area is typically wet and heavy.
After choosing the location, the team installed three test fences – A, B and C - in fall 2007. The fences were constructed in a linear series along the I-90 eastbound embankment slope, west of the Exit 54 (Hyak) off-ramp. The fences were approximately 300-feet long and eight-feet high each, and were subjected to similar snow loads during the winter.

Fence A (see Figure 3) – WSDOT Highway 97A Design – measured 297 feet long and consisted of six-inch square, 12-foot long pressure treated wood posts spaced every 12 feet, with an approximate three-foot post hole depth backfilled with compacted native soil. Fence fabric was made up of two four-foot high, nine-gauge galvanized Solidlock® Fixed Knot high tensile fused wire mesh fabric rolls overlapped by approximately three inches and connected together with nine-gauge galvanized steel hog rings. The fabric was connected to the posts with 1.75-inch nine-gauge staples and to the 3/16-inch stainless steel top cable with 12-gauge hot rings. Nine-gauge galvanized wire tensioners were used at each end of fence for bracing; six-inch square horizontal wood braces at each end of fence were attached to the second-to-last and end-posts (URS 2008).
Fence B (see Figure 4) – Alaska Moose Fence Design – measured 325 feet long and consisted of four-inch diameter, 12-foot long galvanized steel posts spaced every 10 feet, with approximate three-foot pole hole depth backfilled with concrete. Fence fabric was made up of one eight-foot high, nine-gauge galvanized chain link fabric course connected to fence posts with nine-gauge galvanized wire ties. The fabric was connected to end posts with galvanized steel strap brackets using seven-gauge black steel middle and 3/16-inch top tension cable with 12-gauge hog rings. The fence fabric was supported at the top and bottom with seven-gauge tension wire; horizontal galvanized steel braces at each end of the fence were attached to second-to-last and end-posts (URS 2008).

![Figure 4 - Fence B Design.](image)

Fence C (see Figure 5) – Canada Wildlife Fence Design – measured 320 feet and consisted of eight-inch square, 12-foot long pressure treated wood posts spaced every 12 feet, with an approximate three-foot post hole depth backfilled with compacted native soil. Fencing fabric was made up of eight-foot high, nine-gauge galvanized Solidlock® Fixed Knot high tensile wire mesh course with solid lock joints connected to posts with 1.75-inch nine-gauge staples and to the 3/16-inch stainless steel top cable with 12-gauge hot rings. Nine-gauge galvanized wire tensioners were used at each end of fence for bracing; six-inch square horizontal wood braces were used at each end of fence, attached to second-to-last and end-posts (URS 2008).

![Figure 5 - Fence C Design.](image)

The fences were located along the I-90 embankment, down slope of the highway. Due to the steepness of the embankment and loose soil conditions, auguring equipment could not be used to dig the post holes. As a result, all of the post holes had to be dug by hand and some holes could not be dug to the minimum design depth; large rocks impeded the progress of the post hole digging in some areas.

Each fence design also included chain link fabric attached to the bottom of the fence that was buried 18 inches to prevent wildlife from burrowing under the fence. The buried chain link fabric was attached to the fence with nine-gauge galvanized steel hog rings spaced every 18 inches.
The First Season

After installing Fences A, B, and C in 2007, the project team allowed them to sit for one full winter season without repair. In spring 2008, the team inspected the three fences to see how they performed. The inspection parameters included the following:

- **Fence Posts**
  - Failure
  - Rotation/Translation/Pullout
  - Rot
  - Corrosion
  - Loss of Connection

- **Fence Fabric**
  - Failure
  - Deformation
  - Creep
  - Corrosion
  - Loss of Connection

- **Additional Items**
  - Maintenance
  - Aesthetics

2008 inspection findings reveal that Fence A did not perform as well as Fences B or C. Overall, Fence B performed the best. The fabric and fabric connections at all posts, and the buried chain link fabric, were intact for Fence B. Sections of fabric for Fences A and C needed to be replaced and reconnected to the posts as well as the buried chain link fabric. Posts for all fence types needed to be re-plumbed; however, Fence B posts were leaning much less than Fence A and C posts. The metal posts and heavier gauge fencing fabric used for Fence B, though, were judged to be less aesthetically pleasing than the wood posts and lighter gauge fencing fabric used for Fences A and C (URS 2008). Finding a fence design that not only met performance criteria, but also aesthetic criteria for the project, was paramount.

It was evident that repairs on the three test fences were needed before the study could continue for another winter season. Typical problems for all three fences were fabric sag, fabric to post connection failures, and bracing failures. Along with basic repairs to fence fabric and upgrades of fabric connections to posts and strengthened bracing, the team excavated the soil around the fence posts for fences A and C by hand using post-hole diggers and backfilled the holes with concrete.

The team also installed two new test fences, Fence D and Fence E, to analyze two new styles of exclusionary fencing. The two new fences were constructed within the same test section to keep conditions the same.

Fence D (see Figure 6) - Combination Steel Pipe and Cable Fence - measured 230 feet in length and was comprised of four-inch diameter, 12-foot long galvanized steel posts spaced every 10 feet. The post-hole depth was approximately four feet and was backfilled with concrete. Four 3/16-inch diameter stainless steel cables were attached to the posts through drilled post holes spaced evenly in the top three feet of the fence. To test connections, the cables were attached to the intermediate posts with eye bolts on half of the fence and through drilled holes in the posts for the other half of the fence. One half of the cables connected to end posts with steel eye bolts and heavy duty springs. Two 3/16-inch stainless steel (top and middle) tension cables with heavy duty springs attached to the end posts with eye bolts on the other half.
The fence fabric consisted of one five-foot high Solidlock® Fixed Knot high tensile wire mesh course connected to field posts using wire ties; it connected to end posts by wrapping fence wire at the end of the course around the post and twisting around the fabric grid wire. Stainless steel top tension cable (3/16-inch) with 12-gauge hog rings was woven through the wire mesh fence fabric in a looping manner so that the hog rings did not take all the stress. The fence was braced diagonally using galvanized 12.5 gauge high tensile brace wire in the first end bay at both ends of the fence. The fence was braced horizontally using galvanized steel pipe in the first two end bays at both ends of the fence (URS 2010).

Fence E (see Figure 7) - Combination Fiberglass and ElectroBraid® Fence – measured 232 feet and consisted of 12-foot long extruded fiberglass pipe posts spaced every 10 feet, with approximate four-foot post hole depth backfilled with concrete. Five ElectroBraid® lines ran through holes drilled in each post; the lines wrapped around the end post and connected to themselves using bolted clamp connectors.

Fence fabric consisted of one five-foot high Horseman® two-inch by four-inch non-climb wire mesh course with ZA + black paint advanced coating. The fence fabric was connected to field posts using wire ties and end posts. The fabric connected to black steel top and bottom tension cables with 12-gauge hog rings. Diagonal bracing using galvanized 12.5 gauge high tensile brace the wire in two end bays at both ends of the fence; diagonal bracing using extruded fiberglass pipe in the second end bay was used at both ends of the fence. Horizontal bracing using extruded fiberglass pipe was used in the two end bays at both ends of the fence (URS 2009).

Fences D and E did not include buried chain link fabric like Fences A, B, and C due to similar performance of this component of the original fences.

Once the fences were repaired, upgraded and constructed, they were allowed to sit during the 2008/2009 winter season. In the spring of 2009, the team conducted another inspection of the test fence sections built in 2007 and 2008, using the same inspection criteria as before.
The Second Season

Inspection findings in the spring of 2009 indicate that Fences A, B, and E did not perform as well overall as Fences C and D during the winter season. The Fence A design, which included two courses of four-foot high fabric, proved to be less durable during the two winter seasons when compared to the other fences, which use either a single course of eight-foot high fabric or one course of five-foot high fabric with fence cables or ElectroBraid® lines filling the top three feet of the fence. Fence B was a traditional chain link design and was deficient both in connection durability and aesthetics when compared to the other fences (URS 2009). Fence E experienced post failure at the ground line for the majority of the fiberglass posts.

As a result of findings, the team removed Fences A, B, and E. The team then repaired and modified Fences C and D for further consideration.

For Fence C, the team:

- Replumbed all posts to +/- 1 inch as measured from the top of post to ground
- Replaced broken diagonal tension wires and tightened those that were loose
- Tightened top tension cable
- Installed middle tension cable
- Reattached and reinforce fence fabric to top and middle tension wire connection using nine-gauge hog rings spaced every eight inches
- Replaced missing staples at post 16

For Fence D, the team:

- Replumbed all posts to +/- 1 inch as measured from the top of post to ground
- Replaced broken horizontal pipe brace bracket at post 23
- Tightened loose diagonal tension wires
- Tightened top fence cables that run through the posts
- Raised fence fabric to the point where it was originally constructed
- Reattached and reinforced fence fabric to top and middle tension wire connection using nine-gauge hog rings spaced every eight inches
- Reattached fence fabric to posts using larger diameter, higher grade bolts
The fence contractor offered to reconstruct a new Fence E (see figure 10) at its own expense to evaluate alternative post, connection, cable and other materials for consideration in the final fence evaluations. The new Fence E, a combination steel “C-post” and ElectroBraid® Fence, measured 190 feet in length and was comprised of 12-foot long galvanized “C-posts” (slotted square steel tubes) spaced every 10 feet. The post-hole depth was approximately four feet and was backfilled with concrete. Five ElectroBraid® lines were run through plastic support brackets attached to each post, which were spaced evenly in the top three feet of the fence. The ElectroBraid® lines attached to the end posts with steel eye bolts.

The fence fabric consisted of one five-foot high Horseman® two-inch by four-inch non-climb wire mesh course that connected to the field posts using high strength steel bolts and wire ties; it connected to end posts by wrapping fence wire at the end of the course around the post and twisting it around the fabric grid wire. Diagonal braces were connected by wire ties. The fence was braced horizontally using galvanized steel “C-post” tubing in the two end bays at both ends of the fence; braces between the first and second posts were installed horizontally, and braces between second and third posts were installed diagonally (URS 2010).

The three remaining fences, Fences C, D, and E, were allowed to sit for the 2009/2010 winter season. In spring 2010, the team conducted their final planned wildlife fencing performance study inspection.

The Third Season

Inspection findings of the spring 2010 evaluation period indicated that Fence C showed the fewest component failures and did not appear to need significant modifications. Fence D suffered from a significant number of fabric-to-post wire tie failures, which indicated that either the number of ties should be increased to spread the load better, or that the ties should use stronger wire for the connections. Fence E suffered from shearing of the fabric-to-post bolts on most of the posts. It is believed that replacement of the bolts with a top cable, similar to that used on Fence D, would eliminate the connection failure and minimize the downward translation of the fabric to a reasonable and stable one to two inches (URS 2010).
COMPARATIVE RESULTS

The following information highlights overall comparative results of the 2010 evaluation period of the wildlife fencing study.

- Ground conditions such as roadway sand accumulation and downward sloping terrain had a significant impact on overall test fence section performance through the duration of the fence study.
- Additional concrete was used as backfill on the back side of Fences C and D during the 2009 repairs, upgrades, and new Fence E construction.
- Some breaks had occurred in the fence fabric grid wires, but in all cases for each fence, the broken wires were at the posts. This type of failure was most likely due to excessive strain resulting from repeated impact loading, rather than foreign objects within the plowed snow striking the fences.
- Post failure was not found to be an issue for any of the fences. All horizontal and diagonal steel bracing members for Fences D and E, and horizontal and diagonal wooden brace members for Fence C, remained as constructed.
- Post lean was insignificant for all fences.
- Rot and corrosion of the fence posts and wooden or pipe bracing members were not observed to be issues for any of the test fences.
- The three test fences experienced varying degrees of loss at connections to fence posts. Fence C was missing a total of three staples on two posts, but it appeared that they may not have been installed during construction. Bolt connection failures were severe at Fence E, with almost all bolts sheared off. Shearing of bolts on Fences B and D during the 2008-2009 winter prompted the elimination of bolted connections on Fence D, and the trial of larger, stronger bolts on the new Fence E, which still failed in nearly all cases.
- Fence fabric performed very well during the 2009-2010 winter season relating to breakage within the fabric grid. Fences D and E each had one broken wire, with both breaks located at a post. There was no fabric grid failure observed in Fence C.
- All fences experienced some minor deformation in the fabric grid. Fences D and E had vertical wires in the top row of the grid that had slid laterally along the top wire or were bent. Fence C had about two feet of fabric deformed at the bottom of the fence where it came into contact with the ground surface, forcing it to become “warped” in appearance.
- Fence fabric was generally tight for Fences C, D and E. The top four cables for Fence D and all ElectroBraid® lines on Fence E remained tight. All of the diagonal tension wires used for Fences C and D remained tight. Rust accumulation was only noticeable at the posts and cable connectors. Rust occurred on some staples on fence C, the top cables for Fence D, and the ElectroBraid® cable eye bolts on Fence E.
- Loss of connection between fence fabric and posts or tension cables was evident to different degrees for each fence. Fence C had six missing hog rings and three missing staples. Fence D had a large number of missing wire ties at nearly every post. Fence E was missing all wire ties on all diagonal braces and nearly all connection top bolts had sheared off. There was no loss of connection between the fence fabric and the buried fabric or bottom tension cables or wires at any of the fences.
- While each fence had some degree of component failure, the fence that appeared to have performed the best and to need the least number of repairs was Fence C, with only a few hog rings and a few staples needing to be replaced. Only one bay with cable and fabric sag was noted on Fence C.
- Fence D experienced a large number of fabric to post connection wires broken on most posts, which allowed the top cable and fabric to sag one to three inches at each post. The top and middle support cables and cable to fabric connections remained intact.
- Fence E experienced shearing of most top wire connection bolts. Wire ties between fabric and posts remained intact, but the sheared connection bolts resulted in allowing a downward translation of the fabric of between one and three inches on the posts where the bolt was sheared off. All wire ties on diagonal braces were broken or missing. No cable sag was observed (URS 2010).

FINAL WILDLIFE EXCLUSIONARY FENCE RECOMMENDATIONS

In 2010, when the wildlife fencing performance study was complete, the I-90 Project team, consulting staff, and maintenance personnel evaluated how the fencing materials and construction methods held up during each year’s performance study evaluation period. They also reviewed each fence’s construction and maintenance costs, physical engineering, and practical performance in order to determine a recommended final design of the wildlife exclusionary fences for the I-90 Project.

Since the test fences all performed comparably, the team determined, based primarily on initial capital costs and observed performance, that a combination design of Fence D and Fence E (that were constructed for the 2009-2010...
season) along with several minor revisions to maximize performance, would best meet wildlife exclusionary fence cost and performance objectives of the I-90 Project. Aesthetic elements were not considered when determining this recommendation. WSDOT, along with its stakeholders, will evaluate final design elements of the fencing to ensure it will fit into the overall landscape architecture “theme” for the project (URS 2010).

**Final Fence Design Specifications**

The following information highlights the recommended specifications for the final I-90 Project wildlife fencing.

**Posts:**
Three-inch galvanized steel pipe posts with black powder coating, 12-feet long with four feet bury and concrete backfill. All holes for cables will be pre-drilled before hot dip galvanizing and powder coating.

**Braces:**
Brace the first two bays with first bay horizontal and the second bay diagonal, and diagonal black wire braces in both bays. Horizontal and diagonal braces to be connected with galvanized steel fabricated end brackets.

**Fabric:**
Five-foot-high Horseman® two-inch by four-inch non-climb wire mesh course with ZA + Black Paint Advanced Coating.

**Cables:**
Five 3/16-inch stainless steel cables at the top and one 3/16-inch stainless steel cable fabric support cable sown or woven in a looping manner through the fabric. All cables installed through holes drilled through each intermediate post, with heavy duty tension springs at each end post. For very long fences, cable terminations with heavy duty springs every 330 feet to assure that the cables stay taught.

**Cable Connectors:**
Cable-to-end post connections from the cable to the heavy duty spring, with the spring connected directly to an eye bolt through the post. Cable-to-spring connection with the cable looped through the eye of the spring and fastened to itself with a cable clamp. Spring-to-eye bolt connected with a connector link, but without a turnbuckle. Stainless steel cables attached to intermediate posts by running through holes drilled through the posts. Fabric attached to the stainless steel support cable with 12-gauge stainless steel hog rings spaced at 12 inches. Loop cables through the fabric to support the fence without placing all of the stresses on the hog rings.

**Cost:**
The total estimated cost for materials and labor for the recommended fence design (not including taxes, delivery costs, site preparation and equipment) is $25.03 per foot, based on a 660-foot fence length. This recommended design is less expensive than Fence C and Fence E, and only slightly more expensive than Fence D. Both Fence D and Fence E had minor performance issues.

A cost estimate was also prepared for an alternate recommended fence design using “C-posts” and black ElectroBraid lines. The estimated cost for this fence is $25.98 per foot, based on a 660-foot fence, which would be $0.95 per foot more than the recommended design with steel pipe posts and stainless steel cables (URS 2010).

**Maintenance Program**

The project team created an inspection/maintenance program recommendation for the proposed final fence design. The maintenance program should be absorbed within the normal maintenance program, and should be performed annually during the dry spring or early summer months so that any noted installation or material failures can be corrected before the next winter.

1. Perform a general evaluation of the fence environment, including evidence of erosion around the fence, damage by tree limbs or rocks, or other relevant details that could affect the fence performance or reduce its useful life. Take corrective actions to repair or eliminate the potential for additional future damage or reduced effectiveness.
2. Monitor posts for corrosion and for lean or horizontal displacement. Repair or replace any posts that have a lean of more than three inches.
3. Check springs for proper tension. If springs have lost all or most of their tension, re-tension them to the first notch (approximately 150 pounds).
4. Check cables, brace wires and all types of connectors for corrosion or breakage. Replace broken or missing wire clips, hog rings or other hardware.
5. Check fabric for corrosion, sag and loss of connection to the cable and posts. Replace or repair fabric when corrosion starts to cause broken wires or loss of connections. Repair cable to fabric connectors to eliminate sag.
6. Compare the cost of repairs with the cost of total replacement from a full life cycle cost perspective, especially during the last few years of the expected life of the wildlife fence which is estimated to be 18 to 22 years (URS 2010).

Existing Fence Disposition

Since the WSDOT I-90 Project team does not anticipate installing the wildlife fencing until after construction of the corridor is complete (in 2016), the design team has left the three remaining test Fences C, D and E in place and will continue to monitor their performance each spring. The team is not conducting annual maintenance on the test fences to see how they perform unaided over the course of four years. Any component failures or significant deterioration will be noted and the results incorporated into the final fence design. The team plans to remove the test fencing in 2014.

Roadway engineering and construction is an iterative process where multiple considerations must be weighed. For the I-90 Project team, they started their research early in the design process to overcome wildlife exclusionary fence design challenges. They were adaptable and flexible to new ideas and concepts during the three-year performance study, and will continue to remain so as they determine a final fence design that will survive the extreme climate conditions of I-90 Snoqualmie Pass, blend with aesthetic requirements of the project, be cost effective, require reasonable maintenance, and exclude wildlife. The final fence design, which is currently underway, is expected to complete by 2013.

BIOGRAPHICAL SKETCHES

Randy Giles, P. E., is Transportation Supervising Engineer for the Washington State Department of Transportation South Central Region, a position he’s held since 2010. Prior to then, he was I-90 Snoqualmie Pass East Project Director from 2008. Before then, he was a project engineer for the I-90 Project, managing a co-located staff of WSDOT and consultant engineers involved in geotechnical field exploration, geometric design, hydraulic and stormwater engineering. Giles has over 19 years of experience in highway design and construction. He holds a bachelor’s degree in civil engineering from the University of Utah.

Scott Golbek, P. E., is Assistant Project Engineer for the Washington State Department of Transportation’s I-90 Snoqualmie Pass East Project, a position he’s held since 2010. Prior to then, he was Project Engineer for the I-90 Project from 2008. Before then, he was an assistant project engineer for the I-90 Project, managing a co-located staff of WSDOT and consultant engineers involved in geotechnical field exploration, geometric design, hydraulic and stormwater engineering. Golbek has over 19 years of experience in highway planning, design and construction. He holds a bachelor’s degree in civil engineering from the Oregon Institute of Technology.

Steven Kitterman, P. E., is Senior Transportation Engineer for URS Corp., a position he’s held since 2007. In addition to highway and roadway design, he has significant experience in stormwater analysis and design, utilities analysis and design, and utilities coordination. Prior to joining URS Corp., he was with ESM Consulting Engineers since 1987. Mr. Kitterman has more than 34 years of engineering and management experience in all aspects of civil and transportation engineering. He holds a bachelor’s degree in civil engineering from Oregon State University.

Amanda Sullivan is an associate at PRR Inc., where she serves as the company’s central and eastern Washington business development contact and consults for the Washington State Department of Transportation’s I-90 Snoqualmie Pass East Project, a client she’s worked with since 2008. Prior to then, she was a senior staff writer at Executive Media Corp. Sullivan has over seven years’ experience in public relations, public affairs, writing and publishing. She holds a bachelor’s degree in public relations from Central Washington University.

REFERENCES


