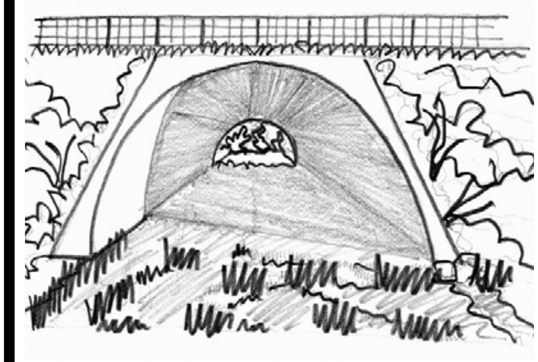
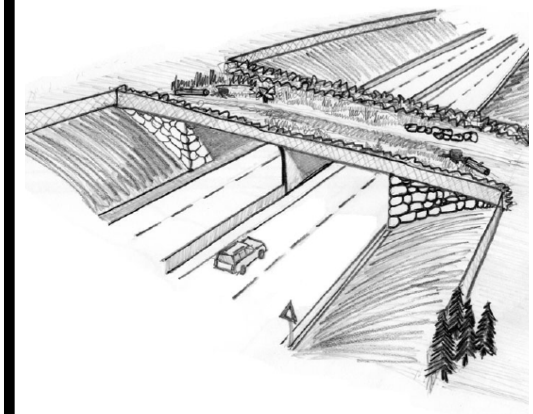
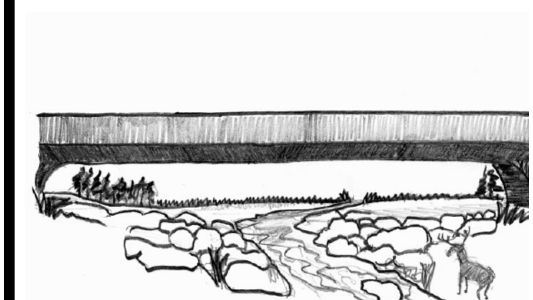
Wildlife Crossings

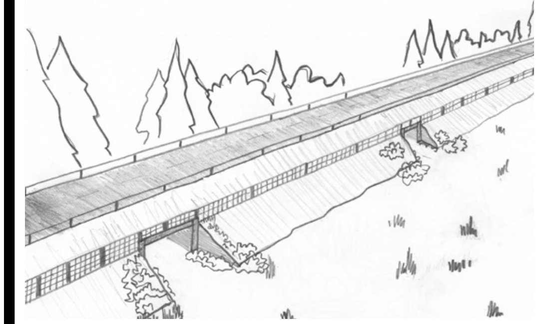
Rethinking Road Design
to Improve Safety and
Reconnect Habitat

Portland State University
Planning Workshop
June 2003









Wildlife Crossings

Rethinking Road Design to Improve Safety and Reconnect Habitat

Project Team
Theresa Carr
Radcliffe Dacanay
Kevin Drake
Charl Everson
Arianne Sperry
Kerri Sullivan

prepared for

Metro

Portland State University
Master of Urban and Regional Planning Program
and the Planning Workshop:

The Master of Urban and Regional Planning program at Portland State University (PSU) provides practicing and aspiring planners with knowledge of history, practice, methodology and a consideration of ethical responsibility surrounding the planning profession. The Planning Workshop is the culmination of the Master's Program and it allows students the opportunity to put their knowledge and skills into practice.

Acknowledgements

The project team would like to thank our clients and faculty advisors. We are grateful for the time and effort they invested in this project and appreciate the support and guidance they provided during the development of this guidebook.

Project Clients, Metro:

Jennifer Budhabhatti
Ted Leybold
Kelley Webb

Workshop Faculty, PSU:

Deborah Howe
Steve Johnson
Connie Ozawa

The project team would also like to thank the following people for their support and assistance:

Linda Anderson, Portland State University
Rob Bertini, Portland State University
Pat Carroll, City of Wilsonville
Sue Gillalan, Multnomah County Animal Services
Mary Gray, Federal Highway Administration
Jim Grimes, Oregon Department of Fish & Wildlife
Jonathan Harker, City of Gresham
Lori Hennings, Metro
Paul Ketchum, Metro
Tom McGuire, Adolfson & Associates
Doug Miller, City of Hillsboro
J.O. Price, Metro
Tony Rufolo, Portland State University
Bob Sallinger, Audubon Society of Portland
Charlie Shell, City of Hillsboro
Carl Springer, DKS Associates
Sylvia Vogel, Oregon Department of Transportation
and our colleagues in the 2003 PSU Planning Workshop Class

Contents

"It is a mistake to draw a distinction between urban and rural areas. We don't have that luxury anymore, as urban areas expand into wildlife areas and the U.S. becomes increasingly urbanized. We have local and migratory wildlife populations that utilize the urban habitat … If the urban area serves as a sinkhole for wildlife, we are going to lose our populations. I think if we write off our urban wildlife populations then we write off our wildlife populations completely."

Bob Sallinger
The Audubon Society of Portland

1.0 Introduction

Metro's *Green Streets* handbook presents methodologies and design solutions for minimizing the impact of roads on the natural environment in the Portland metropolitan region. *Green Streets* includes wildlife crossings as part of its toolkit of options. This guidebook, *Wildlife Crossings: Rethinking Road Design to Improve Safety and Reconnect Habitat*, expands on Metro's previous work and provides guidance on how to develop wildlife crossings in this region.

Wildlife crossings provide animals with safe passage over or under roads. Crossings take many forms; they can be large bridge structures or small culverts. They can serve animals of all types and sizes—from bears to salamanders to butterflies. Wildlife crossings reconnect habitat fragmented by roads and other development and reduce wildlife-vehicle conflicts.

The roads that criss-cross our landscape have signficant effects on natural areas. Not only do roads divide habitat and create barriers to animal movement, roads are a hazard for wildlife that try to cross them. Roadway conflicts between vehicles and wildlife result in vehicle damage, injuries, and the loss of human and animal life.

Although they are most often used in rural areas, wildlife crossings are also needed in urban environments. Even in the Portland metropolitan region, human development encroaches on wildlife habitat as the Urban Growth Boundary expands. And although this region has over 8,000 acres of open space, these patches are not linked in a way that allows animal movement among them. Wildlife crossings are a tool that can help reconnect natural areas to create a regional system of connected greenspaces in the Portland area.

1.1 What is the Purpose of this Guidebook?

This guidebook provides Portland-area planners with relevant information about wildlife crossings in an urban context. While information on wildlife crossings and their effectiveness has been available for a long time, U.S. planners have very little experience with them. In addition, existing information is geared towards rural applications and is not easily transferred to urban environments. It is important to organize this information in a way that is useful to local planners for a number of reasons. First, users should be familiar with the range of available options. Second, there are a number of federal funding alternatives that could be used for wildlife crossings. Finally, there is a need to integrate better wildlife habitat mitigation measures into urban roadway projects.

The purpose of this guidebook is to provide information to planners and community members interested in wildlife crossings or those involved in work on wildlife crossing projects. It contains background information on the need for crossings, provides a context for wildlife crossings in the

Figure 1-1. Over 2,000 deer and elk have been killed in the Portland region over the last ten years as a result of collisions with vehicles.

Portland metropolitan area, describes the variety of design solutions available, and explores issues specific to the planning and construction of wildlife crossings. A few sites in the Portland area that present opportunities for a wildlife crossing are also explored. The guidebook ends with recommendations for the implementation of wildlife crossings in the Portland region.

This book is designed to answer five basic questions that might face a planner or community member considering a crossing to mitigate the impact of roads on wildlife:

1. What types of wildlife impacts do roads create, and how will a wildlife crossing help mitigate them?
2. What should be the goals of a wildlife crossing project, and how should the success of a crossing project be measured?
3. Where should wildlife crossings be located?
4. What design options are appropriate for a given location and road project?
5. What policy issues might affect a wildlife crossing project?

1.2 What are Wildlife Crossings?

Wildlife crossings have a few distinguishing characteristics, which include the following:

- Grade separation
- Vegetation to attract animals and provide habitat
- Fencing and other measures to guide animals to safe crossings
- Strategic location to enhance habitat connectivity and complement wildlife movement corridors
- Adjacent land use and zoning that is conducive to long-term habitat protection

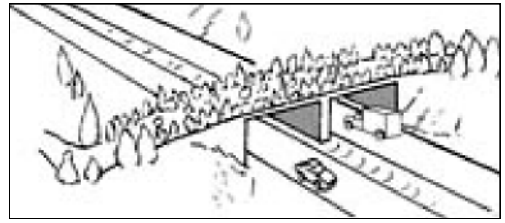


Figure 1-2. Overpass

Figure 1-3. Underpass—Viaduct

Figure 1-4. Underpass—Culvert

1.3 How do we Know that Crossings Work?

In many countries, people have found ways to minimize the ecological impacts and safety issues of roads. For many years, France, Germany, Switzerland, and the Netherlands have applied structural approaches to providing wildlife safe passage across roads. Their documented effectiveness has inspired increasing application in other countries, including Australia, Canada, Slovenia, and the United States.[1] Europeans have conducted extensive research on the effectiveness of their wildlife crossings.

A study of 17 overpasses in Germany, the Netherlands, France, and Switzerland using infrared-triggered video cameras showed that with suitable habitat on and around the overpasses, they were effectively used by a wide variety of animals, including large mammals, small mammals, flightless insects, and butterflies. Another study of a Swiss overpass showed extensive and regular use by badger, fox, marten, chamois, roe deer, and red deer.[2]

Some of the highest profile wildlife crossings span the Trans-Canada Highway where it bisects Banff National Park in Alberta. The 28-mile stretch of highway boasts 24 crossing structures, including two 164 foot-wide overpasses that serve bear, elk, moose, and bighorn sheep, as well as many other species. Over 100 large animals were killed there nearly every year prior to development of the crossings. Since installation, animal mortality has been reduced by 80 percent—as much as 96 percent for ungulates (hoofed mammals).[3]

Along Florida's rapidly suburbanizing State Route 46 in Lake County, more than 100 threatened black bears had been killed each year for several years. The solution was to build a culvert with a flat, dirt floor underneath the highway. The road was elevated so that the bears could see through the underpass to the other side. Follow-up research indicates that up to 55 bears used the underpass in the two years after it was completed.[4] Twelve other species, including bobcat, gray fox, and whitetail deer, are using it, as well.[5]

Every spring in Amherst, Massachusetts, spotted salamanders cross a two-lane road as they come out of their wintering holes.[6] Salamander roadway mortality was high until the community decided to build two culverts with guiding fences at the salamanders' crossing site. The culverts are slotted and drained to maintain the light and moisture conditions preferred by salamanders. Monitoring of the site indicates that more than three out of four salamanders that reached the crossing used the culverts successfully.

The effectiveness of wildlife crossings is influenced by the strategic location of the crossing, the land use surrounding the structure, the existence of habitat around and on the structure, the type of animals that could use the crossing, and various functional design details of the structure (see Chapter 3).[7]

Figure 1-5. Elk using an overpass

1.4 How to Use this Guidebook

The guidebook is organized into seven chapters.

Chapter 1 offers a definition of wildlife crossings and provides a brief description of the conflicts that occur between wildlife and vehicles. Chapter 1 lists the purpose of the guidebook, the intended audience, common misperceptions about wildlife crossings, and examples of effective crossings.

Chapter 2 describes the conflict between our road system and our natural areas. This chapter discusses habitat fragmentation, wildlife mortality, safety hazards to humans, and costs. The chapter places these concerns in the context of the Portland metropolitan region, identifies state and regional plans and programs that are supportive to wildlife crossings, and describes a study recently conducted by Metro on wildlife mortality.

Chapter 3 outlines a number of potential wildlife crossing design solutions, accounting for wildlife movement corridors, the species of interest, adjacent land use, topography, crossing type, and road width. The design options described in this section include riparian culverts, upland culverts, viaducts, and overcrossings. Chapter 3 describes fencing and alternative measures, costs to construct and maintain different types of crossings, and situations where a multipurpose crossing could be appropriate.

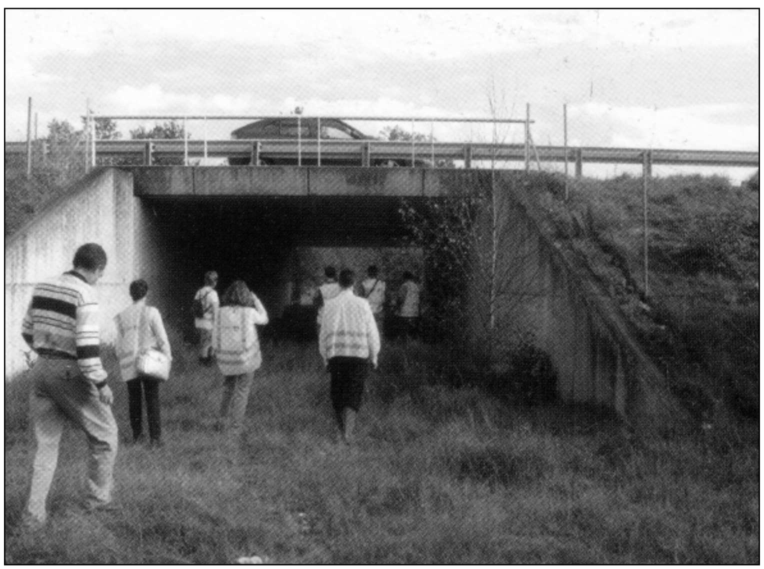


Figure 1-6. Box culvert (France)

Chapter 4 summarizes a number of factors to consider when implementing a wildlife crossing. These include possible federal, state, and local funding options, regulatory opportunities, and road design classifications.

Chapter 5 summarizes the information in this guidebook and provides a list of questions that planners should address when considering a wildlife crossing. These questions address the need for a crossing, the goals of a project, viable and appropriate sites, effective crossing design, and implementation issues.

Chapter 6 describes local applications of wildlife crossings, and identifies three opportunity sites around the region, including Cooper Mountain-Tualatin River in Washington County, Boeckman Road in the City of Wilsonville and Mitchell Creek in Pleasant Valley.

Chapter 7 provides recommendations on how to start implementing wildlife crossings in the Portland region. These include improving wildlife mortality data collection efforts, encouraging the inclusion of wildlife crossings in the Metropolitan Transportation Improvement Program (MTIP)-eligible projects, and coordinating with other agencies on potential cost-sharing opportunities.

"Look deep into nature, and then you will understand everything better."

Albert Einstein

1.5 Who Should Use this Guidebook

Transportation planners and engineers

This document will be of use to transportation planners and engineers interested in exploring the feasibility of wildlife crossings in the Portland region.

Developers

Developers who design and build residential, commercial, or public works projects can use this guidebook for ideas on how to mitigate environmental impacts associated with development. Developers will find guidance on what information is needed at the beginning of a project's design, and ideas on costs and funding options. Crossings could help keep mitigation costs to a minimum while adding aesthetic value to a development project.

Wildlife biologists and environmental planners

The road crossing alternatives described in this guidebook, as well as the funding options, costs, and regulatory considerations, should provide wildlife biologists and environmental planners with information to help develop a crossing.

Citizens

Citizens of the Portland region have voiced a desire to maintain a high level of environmental integrity within the metropolitan area. This guidebook can help residents to consider how best to implement these crossings in an urban environment.

1.6 Understanding Common Barriers to Implementing Wildlife Crossings

As illustrated in Section 1.3, most wildlife crossings in the United States are located in rural areas where highways bisect large tracts of habitat. The lack of experience with wildlife crossings in urban areas comes into play especially when a road project that includes a wildlife crossing moves forward from the planning stage to design and construction. If a wildlife crossing is included as an amenity of a road project, and is not considered essential to the project's success, it could be deleted from the project design if it threatens or is perceived to threaten the project's schedule. Some developers or jurisdictions could perceive the wildlife crossing as having the potential to delay the project through the permitting process or through the funding procurement process. Added costs of building a crossing may also threaten a project's viability.

Most agencies and firms are wary of project add-ons that could push their project over budget, and of including elements that are perceived to require substantial maintenance funds. Although this is not often the case with wildlife crossings, it is a common barrier to be addressed.

Naturally, whenever a wildlife crossing is being considered, an analysis of relative benefits should be conducted to ensure that a true need for the crossing exists. Real concerns raised through this process should be addressed before constructing any crossing. However, other criticisms may be based on incomplete information or lack of understanding of the issue. Figure 1-7 highlights a number of commonly heard misconceptions, based on a series of interviews with planners in the region and a survey of fellow PSU Workshop students.

Figure 1-7. Common Myths About Wildlife Crossings

Myth	Reality
1. There are no wildlife species in the Portland region.	Wildlife do exist in this region. Metro's Goal 5 program has developed a list of wildlife species that includes over 200 species of birds and over 50 species of mammals that live in the Portland metropolitan area, including deer, elk, bobcat, and peregrine falcons. See Appendix B for a selected list of mammals, amphibians and reptiles in the region.
2. Wildlife crossings will increase the number of unwanted wildlife species in residential and commercial areas built for humans.	One of the objectives of Metro's Greenspaces Master Plan is to connect land acquired by Metro for habitat linkage. If designed properly, crossings can work to divert wildlife from entering residential and commercial areas built for humans, by providing a direct corridor of designated wildlife habitat.
3. Project budgets are very tight, and there is no extra money available to build wildlife crossings.	Wildlife crossings are eligible for federal and state funding, and in many cases this funding is additive. This means that building a crossing will not impact the overall project budget, just provide more 'bang for the buck.'
4. My proposed development impacts environmentally sensitive areas, and I don't want to add anything to my project for fear that the permit will not be approved.	Wildlife crossings can be an effective way of meeting environmental mitigation requirements set by federal reviewing agencies. Instead of triggering a permit, the crossing may help a permit get approved.
5. Building a wildlife crossing will require special review and approvals, which will delay my project and put it over budget.	The majority of wildlife crossings can be built within an existing roadway footprint. Building or retrofitting any structure over a wetland or stream will require participation from regulatory agencies. However, as stated above, a wildlife crossing is typically seen as a way to mitigate an environmental concern, not as a problem itself.
6. Our environmental focus right now is on endangered species, and this means retrofitting our culverts for better salmon passage.	Many riparian culvert projects can be combined with fish culvert projects. When retrofitting a fish culvert to improve salmon (or other fish) passage, consider increasing the size of the culvert to also accommodate other wildlife. Combined fish/wildlife culvert projects have potential cost- and funding-sharing opportunities.

This page left blank intentionally.

“What is huge, conspicuous and avoided by ecologists? The road network etching the land appears to be the only spatial element that essentially all landscapes have in common.”

Richard Forman
in Pine Barrens: Ecosystem and Landscape

2.0 Road and Wildlife Conflicts in an Urban Context

2.1 Wildlife Impacts

Roads, highways, and other types of transportation infrastructure have impacts on wildlife and wildlife habitat that are disproportionate to the area of land they occupy. While roads cover approximately one percent of the United States, it is estimated that 15-20 percent of the landscape is directly affected by roads and vehicles.[1] Because of their impervious surface, roads lead to increased flow of stormwater run-off which interrupts the hydrologic cycle, alters stream structure, and degrades the water quality of streams.[2] Roads can also act as physical barriers to wildlife movement, disrupting wildlife migration patterns and population dynamics by leaving segments of a wildlife population isolated from one another.

Figure 2-1. Roads can act as physical barriers to wildlife movement.

Metro region

The natural landscape of the Metro region has experienced a great deal of change over time. Although more than 8,000 acres of parks and greenspaces have been protected, urbanization has had many adverse ecological impacts on wildlife populations and natural systems due to the steady increase in roads and other impervious surfaces, loss of streams, and reduction in tree canopy cover. Between 1980 and 2000, the region gained over 500,000 new residents. During roughly the same time period, over 1,800 miles of roads were built, bringing the total road miles in the region to over 5,000 miles (see Figure 2-2).[3] A recent study of tree canopy cover in the Willamette/Lower Columbia Region found a reduction from 46 percent in 1972 to 24 percent in 2001. In the region's urban areas, average tree canopy cover is only 12 percent, down from nearly 21 percent in 1972.[4] It is estimated that the Metro region has lost approximately 400 miles of free-flowing streams (about 30 percent of the original) to culverts and other diversion techniques.[5] Furthermore, the Oregon Department of Environmental Quality (DEQ) recently reported that 213 miles of streams throughout the region were listed as "water-quality limited."[6]

These changes are especially significant for wildlife, as trees and streams serve important functional roles in providing habitat for a variety of species. There are many regional efforts underway to conserve, protect, and restore these natural areas through a variety of goals, policies, and programs. Much of the region's remaining wildlife habitat is now concentrated in these protected areas. Some of the region's largest natural areas, such as Forest Park, Powell

Butte, and Oxbow Park are becoming increasingly important stopping points for migratory wildlife populations because of their connection to major wildlife migration corridors (such as the Coast Range). These large natural areas are also important habitat for migratory songbirds as they pass through the region. Due to their relatively high amount of critical interior habitat (habitat that is insulated from human disturbances) and their connection to major wildlife migration corridors, these large habitat patches are able to support a diversity of wildlife species. We can get the most value from remaining habitat by protecting and restoring safe connections between existing habitat patches.

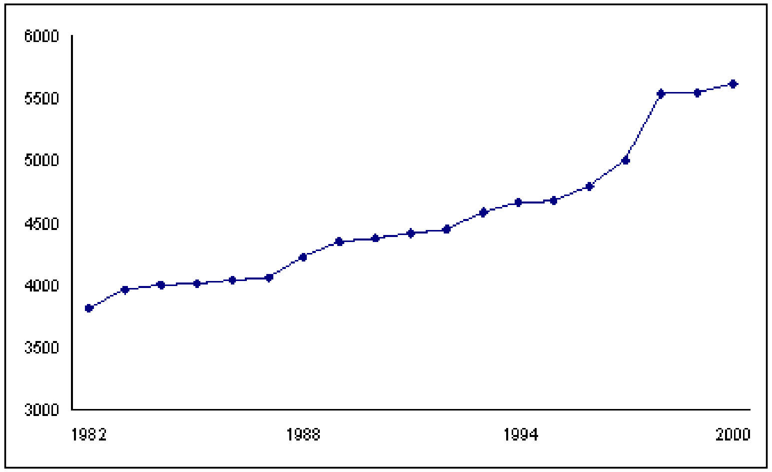


Figure 2-2. Over the past two decades, more than 1,800 miles of roads were built in the Portland region.

Different species, different needs

Different wildlife species require different types and sizes of habitat for survival. In general, the larger the animal, the more land it needs for survival. For example, a deer forages on a much larger range than a mouse. Predators require an even larger area of land, because the land must support enough prey for their survival.

One useful distinction is the difference between animals that are "generalists," and those that are "specialists." Habitat generalists, such as raccoons and deer, can utilize many different types of habitat and adapt well to the presence of people. Most non-native species are generalists. These wildlife species can thrive in urban areas if certain habitat elements are provided in the context of urban development.[7] Habitat specialists, however, are more sensitive to roads and human activity and require access to larger patches of habitat. The Steller's Jay and Winter Wren, for example, are native specialist species that require interior habitat that is relatively undisturbed. Preservation of native species in urban environments requires a more comprehensive, regional effort that establishes and protects wildlife movement corridors and connections between smaller habitat patches.

> *As many as 62 mammal species use the forest habitat of Forest Park.*
>
> *Portland Parks and Recreation*

Habitat fragmentation and patch size

Roads fragment wildlife habitat into smaller patches of various shapes and sizes and reduce the connectivity necessary for maintaining species diversity and preventing local extinctions. Large patches have a high value to native wildlife because of the valuable interior habitat they provide. As patch sizes get smaller, interior habitat decreases while the amount of edge habitat increases. This is known as the edge effect, which increases with habitat fragmentation (see Figure 2-3). Edge effects can penetrate far into the interior portion of a patch of habitat and lead to the invasion of exotic plants and increased predation.[8] In Forest Park, recent studies have suggested that edge effects can extend 250-350 feet from the edge into the interior of the forest.[9] Edge effects decrease the number of native species a given patch can support. Ultimately, larger patches with more interior habitat have a higher value for native wildlife because they reduce the competition from non-native and generalist species. Nonetheless, providing safe connections between smaller patches is still important.

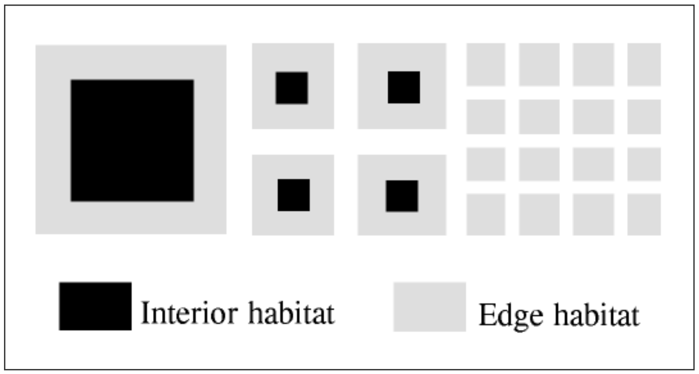


Figure 2-3. Relationship between patch size and edge effect: Studies suggest that edge effects can extend 250-350 feet from the interior of the forest.

Wildlife movement corridors

The long-term health of wildlife populations is directly related to the total amount of available habitat. Many wildlife species move between small habitat "islands" that are individually too small but collectively add up to a home range that meets their habitat requirements. This constant movement of wildlife also helps to maintain genetic variation among wildlife populations, which is essential for the survival of regional populations. The ecological consequences of subdividing wildlife populations can include isolated gene pools, disease, inbreeding depression, and a substantial increase in the vulnerability to extinction. Wildlife corridors in urban areas also allow for the safe out-migration of wildlife to larger habitat areas outside the urban area. "Wildlife corridors can be viewed as a kind of landscape health insurance policy—they maximize the chances that biological connectivity will persist, despite changing political and economic conditions."[10] Identifying important connectivity zones and wildlife movement corridors and providing safe connections between remaining habitat patches can help reduce many of the ecological impacts of habitat fragmentation. For example, the Pleasant Valley

In the Metro region, nearly half of all native vertebrate species depend on riparian habitats, with 93 percent using riparian areas for breeding or feeding.

Concept Plan includes a habitat linkages map that identifies wildlife movement corridors. The plan incorporates measures for avoiding disturbance of those corridors, such as vacating a roadway and building bridges over critical habitat areas.[11]

Habitat connectivity and riparian areas

Most wildlife species require access to streams and riparian areas to fulfill their lifecycle requirements. Since roads commonly follow waterways, they often impact stream dynamics and create a barrier to wildlife movement by limiting wildlife access to riparian areas. Culverts are necessary in places where roads intersect with waterways, but are typically designed to allow only for water conveyance, not wildlife movement or habitat connectivity. Since the federal listing of Chinook salmon and other fish species under the Endangered Species Act (ESA), great efforts have been focused on restoring fish habitat and stream connections where roads intersect with streams. Some culverts are now being designed to maintain natural stream dynamics and allow for uninhibited movement of both fish and wildlife (see Chapter 3 for more information on culvert designs). Since riparian areas serve critical habitat functions for native terrestrial animals as well as for fish, it is also important to restore and maintain connectivity between upland habitat areas and nearby streams.

Urban implications

Because of the temperate climate, abundance of rivers and streams, and lush vegetation, the Portland metropolitan area is home to a great diversity of wildlife. The loss of urban wildlife populations has significant social and ecological costs and broad implications on the quality of life for all residents of this region. Many residents in the Metro region place a high value on proximity to nature and natural areas. Preservation of natural areas in the urban environment guarantees places of refuge for both humans and wildlife. The loss of urban wildlife habitat also means a loss of parks, greenspaces, and other urban assets that have a high recreational value to humans. The overall health and resiliency of ecosystems, whether urban or rural, is dependent on native wildlife diversity. Without sufficient habitat for all native species, ecosystems are easily thrown out of balance.[12] If we ignore the needs of our urban wildlife populations, we dismiss our wildlife populations overall, says Bob Sallinger, Director of the Audubon Society's Wildlife Care Center.[13] If species are to exist, it is the responsibility of all humans, even those in urban areas, to live with them.

"A connected system of parks and parkways is manifestly far more complete and useful than a series of isolated parks."

Frederick Law Olmstead
Report to the Portland Park Board, 1903

2.2 Safety

While there are no comprehensive and reliable data sources for assessing the number and nature of animal-vehicle conflicts in the United States, it is widely accepted that the extent of the problem is great enough to warrant the attention of transportation officials, planners, and engineers. The number most often quoted is one million vertebrates killed by cars every day.[i] That comes out to almost 400 million animals each year, which makes cars the number one human-related cause of death to animals—more than hunting and animal experimentation combined.[14]

Other estimates suggest that animal-vehicle collisions result in the deaths of one million "large" animals on U.S. roads every year.[15] Conover et al.[16] estimated that each year, cars hit 1.5 million deer, resulting in 29,000 human injuries and 200 deaths.

Figure 2-4. One million vertebrates—animals with a backbone—are killed on U.S. roads each year. These collisions cause human injuries and sometimes fatalities.

Both the National Safety Council and the National Highway Traffic Safety Administration (NHTSA) estimate that animal-vehicle conflicts account for about four percent of all automobile crashes.[17] According to NHTSA, of the 292,000 animal-vehicle collisions estimated for 2001, 19,000 resulted in human injury and 165 resulted in loss of human life.[18]

However, these sources make their estimations based on documented incidents, and animal-vehicle conflicts have been found to be highly underreported. One study at Cornell University found that for every reported deer kill, four more died and one more was injured.[19] While it is difficult to quantify the extent of the underreporting, many believe the actual number of animal-vehicle conflicts to be at least two to three times higher than the number of reported incidents.[20]

Another aspect of this issue is that the number of wildlife-related vehicle accidents appears to be on the rise. Hughes et al.[21] studied data from the Highway Safety Information System at University of North Carolina and found that animal-vehicle conflicts increased 69 percent between 1985 and 1991. The study suggested that human destruction of and encroachment into animal habitat was the main reason for the increase, and predicted that these trends would continue as more roads are built and more wild lands are developed.

As at the national level, comprehensive and reliable data on wildlife-vehicle conflicts are difficult to find for the three-county Portland metropolitan region. The Oregon Department of Transportation (ODOT) records two types of wildlife-related accidents—those in which an animal is merely involved and those during which an animal is actually struck. Over

[i] This widely-referenced figure appears to come from a field survey conducted by the Humane Society in the 1950's. During the 1970's, the Humane Society compiled data from numerous sources to come up with a similar number (Braunstein, 1996).

The Quest for Good Wildlife-Vehicle Conflict Data in the Portland Region:
A Metro study assessing deer and elk road-related mortality

One of the overarching objectives of Metro's Parks and Greenspaces Department is to protect and restore the region's biodiversity. With the recent acquisition of additional open space, bringing the region's total to more than 8,000 acres (discussed in Section 2.5), Metro established a goal of reconnecting these protected areas to allow for wildlife movement and began to investigate wildlife crossings as a way to re-establish wildlife corridors divided by roads. The agency set out to establish the necessity and feasibility of wildlife crossings by researching the extent of the wildlife-vehicle conflict problem through data collection and analysis.

Metro compiled wildlife mortality data for the three-county Portland region from several sources, including:

- City, county, and state road maintenance department roadkill pick-up records
- ODOT's Crash Analysis and Reporting Unit
- County animal control agencies
- Animal care and rehabilitation centers.

The study, which was completed in August of 2002, reported more than 2,000 deer and elk deaths between 1992 and 2001 due to collisions with vehicles.* Figure 2-5 shows the deer and elk mortality locations in relation to roads, protected greenspaces (Metro-owned land, parks, and designated open space) and "wildlife movement corridors."**

The analysis of wildlife mortality "hot spots" was limited to elk and deer due to the lack of available data—many agencies do not consistently report other wildlife mortalities. Additionally, the hot spots study was conducted only on Clackamas County data due to limited data availablity in the other counties.

The Metro study identified a number of "hot spots"—locations with high wildlife mortality—in Clackamas County, and offered a few other conclusions:

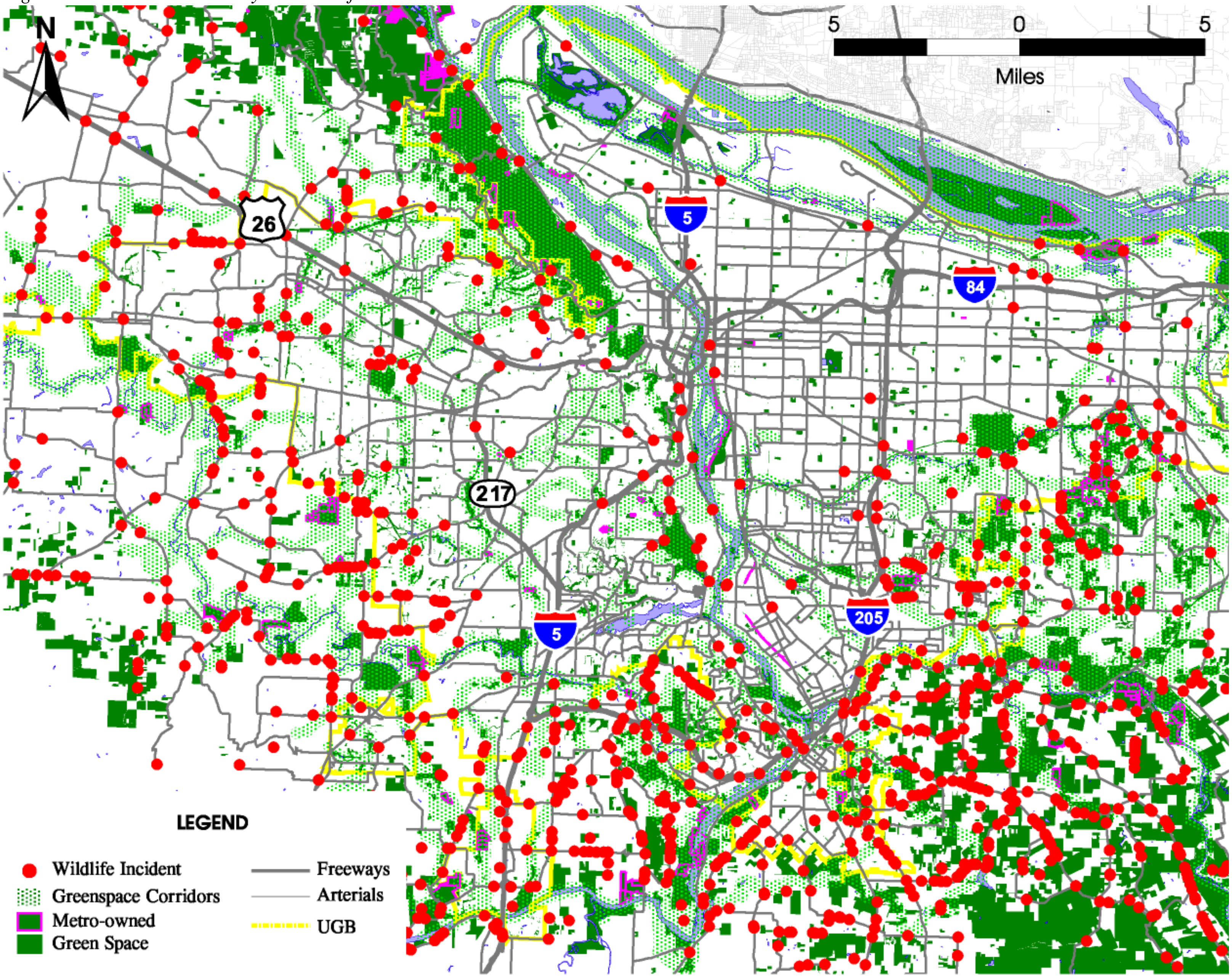
1. The deer and elk mortalities are not distributed equally across all roads—the data are non-random. However, the analysis could not determine the factors responsible for the clustering. Characteristics mapped in a Geographic Information System (GIS), such as land use, water features, vegetation, etc., have not shown a significant correlation.
2. Deer and elk mortality peaks in the autumn. The peak coincides with breeding time, which brings about a general increase in wildlife movement.
3. Jurisdictions that have wildlife mortality reporting systems and keep accurate records will appear to have a higher concentration of wildlife-vehicle conflicts than jurisdictions that keep less consistent records, regardless of the number of actual incidents.
4. A more comprehensive and consistent regional approach to data collection and reporting is necessary in order to identify true "hot spots" in the region.
5. A field survey should be undertaken to compare ground-level differences in factors such as habitat quality between roads that have high rates of wildlife mortality and those that do not.

---

* The study also reported 173 deaths in part of the year 2002.

** The wildlife movement corridors are unofficial estimates drawn up by the Greenspaces Technical Advisory Committee, based off of riparian corridors.

Figure 2-5. Deer/elk mortality and wildlife movement corridors



the last ten years, there were roughly 1,500 crashes *involving* wildlife in the region (see Figure 2-6). Of these crashes, 625 (42 percent) resulted in human injury and two resulted in death (injury to or death of the animal is not recorded).[22] Collisions where the animal was *struck* accounted for an additional 753 crashes. Of these crashes, 196 (26 percent) resulted in human injury. These data from ODOT account only for crashes causing human injury or property damage

Figure 2-6. Two Ways of Counting Crashes involving Animals in Three-County Portland Region, 1992-2001

	ODOT Data		Metro Study
	Animal involved	Animal was struck	Deer & elk only
1992	137	61	35
1993	128	68	28
1994	153	53	21
1995	161	86	52
1996	163	67	165
1997	128	68	159
1998	168	86	245
1999	167	98	392
2000	137	86	479
2001	158	80	466
10-year Total Crashes	1500	753	2042

greater than a certain threshold[ii] that are reported to the state Department of Motor Vehicles. As with the national statistics, many wildlife-vehicle conflicts in the Portland region are unreported or unrecorded. A study recently conducted by Metro to assess wildlife mortality due to roads (see page 14) illustrates the problems with data collection and reporting, and shows how data can vary depending on the source.

Bob Sallinger, director of the Audubon Society of Portland's Wildlife Care Center, reports that between 300-400 animals are brought to the center each year due to vehicle-related accidents. This accounts for up to 12-16 percent of all the injured animals the care center receives each year.[23]

The problem of animal-vehicle conflicts is likely to increase as the region's population grows. The metropolitan region is projected to add over 500,000 people by 2020, reaching a population of 2.3 million.[24] As the region grows, more and more land will be developed for urban uses.[iii] It is inevitable that, as people pave over habitat to make room for their own uses, there will be more and more collisions—both figurative and literal—between humans and animals. Planning for ways to alleviate the conflict between vehicles and animals can greatly improve the safety for both animals and humans.

It is inevitable that, as people pave over habitat to make room for their own uses, there will be more and more collisions—both figurative and literal—between humans and animals.

[ii] Legally reportable crashes are those involving death, bodily injury or damage to any one person's property in excess of $500 through August 31, 1997 and $1,000 or more after that date.

[iii] State law (ORS 197.296) requires Metro to periodically expand the Urban Growth Boundary to maintain a 20-year land supply inside it. In the latest expansion in December 2002, an additional 18,700 acres were brought inside the boundary and made available for development (Metro, 2002).

2.3 Cost of Wildlife-Vehicle Conflicts

It is important to consider the implications for safety and wildlife when weighing the costs and benefits of a road or wildlife crossing project. It is useful to divide the costs into "direct" costs and "indirect" costs to understand the implications of wildlife-vehicle conflicts.

"Direct" costs

Direct costs are those costs that can be quantified, such as vehicle damage, wildlife clean-up, and cost of injuries.

Vehicle damage

Vehicle damage costs vary depending on many factors, including the size of the animal involved, the vehicle's speed, and the type of vehicle. The Insurance Information Center for Oregon and Idaho estimates the average vehicle damage claims for deer- and elk-related incidents to be $2,000 per incident in 1997.[25]

Accident clean up

Like vehicle damage costs, accident cleanup costs depend on many accident-related factors. The Clackamas County Department of Transportation and Development estimates the cost of dead deer pick-up to be $120 per animal in the year 2001-2002.[26] A study in British Columbia in Canada estimates the cost of animal pick up to be $25, $100 and $350 (Canadian) for small, medium and large animals, respectively.[27]

Human injuries

The cost of wildlife-related accident injuries in the United States was estimated to be $146 million in 2001.[iv] This estimate includes lost wages and productivity, emergency services, and medical expenses. The average cost for a nonfatal injury is estimated to be $36,500.[28]

Figure 2-7. The average vehicle damage claim in Oregon and Idaho for deer/elk-related conflicts was $2,000 per incident in 1997.

"Indirect" costs

Indirect costs are those that are not easily quantifiable, such as loss of human and animal life. They also include intangible costs, such as pain and suffering and lost quality of life due to human injuries. Some scholarly work has attempted to estimate the comprehensive value of wildlife and human death and injury.[29] Placing a monetary value on these types of costs presents quite a challenge, however, because they are highly dependent on personal and cultural values. Although these costs cannot be easily measured for a cost-benefit framework, they should be taken into consideration when weighing the impact of a road project.

[iv] This figure was calculated by estimating the average cost for nonfatal injury (as designated by the National Safety Council) and multiplying it by the number of animal-related injury accidents.

2.4 State and Regional Planning Goals

Metro's Title 3 protects fish and wildlife habitat areas in the Portland metropolitan region by controlling the kinds of development that can take place in those areas. Title 3 is the regional implementation tool for State Goals 5, 6, and 7 and is found in Section 6 of Metro's *Urban Growth Management Functional Plan*. Goal 5 of Oregon's Statewide Land Use Goals calls for protection of the state's natural resources and conservation of scenic and historic areas and open spaces,[30] and requires a statewide inventory of riparian areas, wetlands, and wildlife habitat, among other natural assets. It also provides guidelines for planning and implementation of this regulation.

The purpose of Title 3 is twofold: protect water quality and floodplain areas, and protect fish and wildlife habitat. Title 3 describes specific performance standards and practices that jurisdictions can adopt in their local codes. Title 3, which is still in development, will apply to development in Fish and Wildlife Habitat Conservation Areas.[31] Wildlife crossings that are designed to protect habitat by restoring or maintaining habitat connectivity may help satisfy Title 3 policy requirements.

2.5 Metro Programs

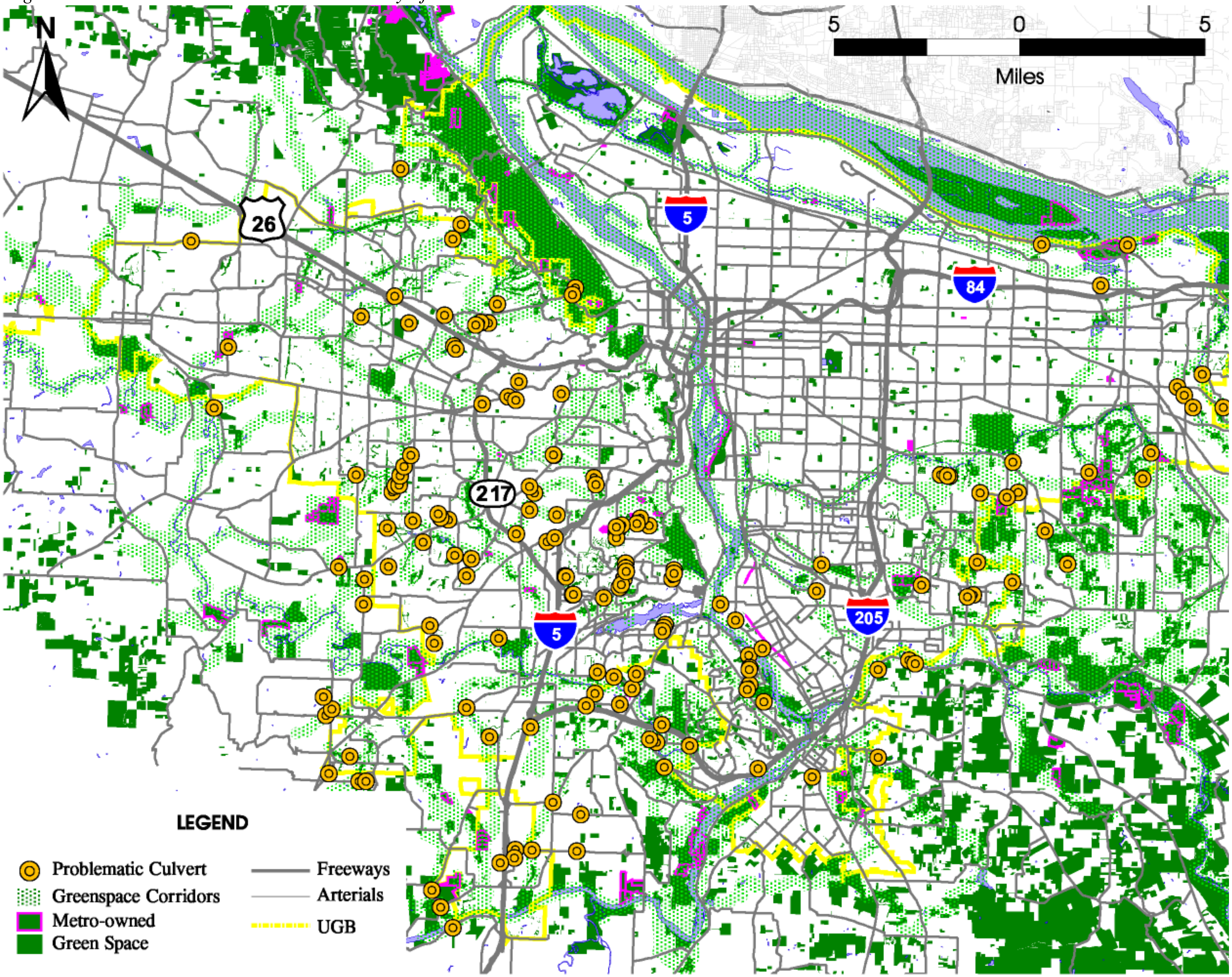
Metro sponsors a number of programs related to habitat protection and the mitigation of road impacts on wildlife and wildlife habitat. Three of these programs—the Metropolitan Greenspaces Program, Culvert Inventory and the *Green Streets* handbook—are directly supportive of mitigating the problem of wildlife-vehicle conflicts.

Culvert Program

Metro's culvert program has ranked the culverts in the region to identify those needing repair or replacement to accommodate endangered or threatened fish species[32] (see Figure 2-9). Funding through MTIP could be used to begin this process. The culvert program was initiated after Pacific salmon and steelhead were added to the ESA listing in the State of Oregon as threatened or endangered species.[33] While the focus of Metro's culvert program is directed at fish passage, the identification of problem culverts presents opportunities to develop wildlife crossings that accommodate fish as well as other wildlife.

Figure 2-8. The identification of problem culverts presents opportunities to develop wildlife crossings that accommodate fish as well as other wildlife.

Figure 2-9. Culverts listed in Metro's Inventory of Problematic Culverts



Metropolitan Greenspaces Program

The Metropolitan Greenspaces Program articulates a vision for an interconnected system of parks, natural areas, greenways, trails, and open spaces. Since 1995, Metro has acquired over 8,000 acres of open space. This includes roughly 50 miles of stream and river frontage as well as wetlands, riparian areas, meadows, forests, and other valuable habitat.[34] Connectivity between these natural areas is key for promoting biodiversity in the region. Wildlife crossings may serve as a helpful tool for maintaining and restoring habitat connections across roadways.

Livable Streets Program

Metro's *Green Streets* handbook, part of the Livable Streets Program, takes a watershed-based approach to transportation planning by providing methodologies and design solutions to minimize the negative impacts of stormwater runoff caused by the impervious surfaces of streets. The purpose of the *Green Streets* program is to minimize the impact of streets on the surrounding environment, especially in areas that are environmentally sensitive.[35] Wildlife crossings can further promote the quality of the region's stream system and minimize the impacts of roadway projects on wildlife populations.

Road design classifications

The road design classifications for the Portland region were established by Metro as part of the 2040 Growth Concept Plan.[36] The intention of the classifications is to define how all roadways will accommodate different travel modes and local and regional transportation needs. Road design classifications affect funding procurement, and impose design requirements on right-of-way width, sidewalks, landscaping, and bike lanes. Wildlife crossings will need to comply with the width of roadways as defined through the design classifications. The categories of road design classifications include:

Throughways—connect major activity centers, industrial areas, and intermodal facilities. Emphasize movement of automobiles.

Boulevards—serve urban activity centers. Emphasize public transportation, bicycle, and pedestrian travel.

Streets—serve transit corridors, residential areas, and main streets. Integrate many modes of travel and accommodate public transportation, pedestrian, and bicycle travel.

Roads—emphasize automobile travel, but accommodate all modes of transportation.

Local streets—oriented towards local residential neighborhoods.[37]

For more information...

Please refer to the following documents for more information on topics covered in this chapter.

1. **Metro, Portland, Oregon**. 2002. Green Streets: Innovative Solutions for Stormwater and Stream Crossings.

2. **Metro, Portland, Oregon**. 2001. Metro's Open Spaces Land Acquisition Report to Citizens.

3. **Metro, Portland, Oregon.** 2003. Website: *http://www.metro-region.org*

4. **Land Conservation and Development Commission.** 2003. Oregon's 19 Statewide Planning Goals & Guidelines. Website: *http://www.lcd.state.or.us*

5. **Metro, Portland, Oregon.** 2000. Regional Transportation Plan.

"When urbanization is occurring, habitat fragmentation is inevitable and one of the only practical mitigation measures is the establishment of corridors of natural habitat or linkages, such as underpasses, that permit dispersal across barriers."

M.E. Soule
Conservation Biologist

3.0 Effective Design Solutions
Considerations for wildlife crossing designs

There are ways to design wildlife crossing structures to be more effective. This section highlights a number of the issues that can make the difference between a mediocre crossing and a successful one.

Before making decisions about the type of crossing or its design, it is important to determine the goals of a proposed wildlife crossing. The project goals will determine how the effectiveness of the crossing will be measured and will also inform the design decisions. Is it important to restore or maintain habitat connectivity, or is the goal to reduce road mortality and increase safety for drivers? Is the crossing intended for a wide variety of species, or is it targeted to just one sensitive species?

As mentioned in Chapter 2, different species have different needs. Some animals, such as rodents, favor covered, enclosed spaces, while others, such as elk, prefer a wide expanse that enables them to see great distances. A wildlife crossing tailored to the mouse may not be suitable for the elk, and vice versa. In general, the more a wildlife crossing resembles the surrounding habitat, the more effective it will be for a wide variety of species. Therefore, large, wide overcrossings that appear as uninterrupted habitat are effective crossings, as are viaducts and bridges that span ravines and riparian corridors and preserve the integrity of the underlying habitat. However, most wildlife crossing projects have many goals, including cost minimization. This chapter examines the ways that crossings can be designed to meet those goals.

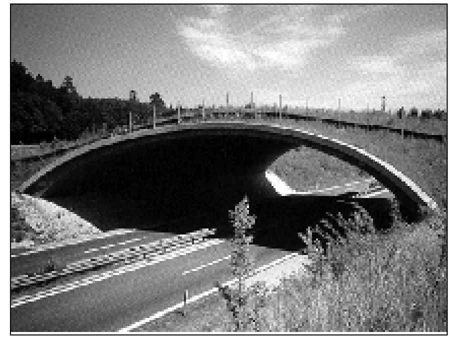


Figure 3-1. Overpass

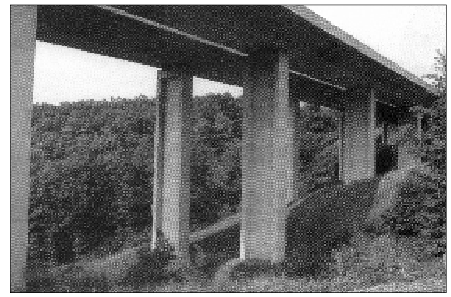


Figure 3-2. Viaduct

Figure 3-3. Upland Culvert

Figure 3-4. Riparian Culvert

3.1 Making your Crossing Work for You: Factors for successful crossings

Location, location, location

Land use

One critical factor when considering an effective location for a wildlife crossing is present and future land use. Wildlife crossings must connect habitat. Examples from Europe show that the existence of adjacent habitat is probably the most important determinant of crossing effectiveness.[1] Because land use is subject to change, it is usually best to locate crossings on land that is set aside as open space or has a conservation easement or some other designation that limits development. In Florida, the Florida Fish and Wildlife Conservation Commission purchased the land adjacent to a bear underpass to ensure continued access to the crossing.[2] In Europe, local governments form agreements with landowners to retain adjacent habitat.[3] Planners in southern California learned a lesson after researching and building a system of several wildlife underpasses along Highway 241, only to find their integrity compromised by subsequent adjacent development.[4]

Wildlife corridors

Crossing placement should also take into account the natural movement of animals in the area. Some animals move along the same corridors year after year, crossing roads in approximately the same place every time. Crossings should be located to intersect with existing wildlife corridors in order to minimize disruption of migration patterns, reduce the amount of fencing needed, and maximize crossing effectiveness. (See Appendix A for more information on identifying wildlife corridors and "hot spots.")

Topography

Topography is another key factor that should influence crossing location. This is true for several reasons. First, topography influences wildlife movement patterns. Animals often migrate through valleys and along stream corridors, and therefore these areas should be considered first when deciding on crossing location. Secondly, from an engineering standpoint, certain topographies lend themselves to crossings, while others prove more difficult. Topography also affects the type of crossing that may be appropriate, and makes certain crossing types more effective than others. Specifically, viaducts (elevated roads generally used over valleys or bodies of water) are considered highly effective because they leave the ecosystem virtually untouched and allow species of all types and sizes to pass underneath.

Size matters

Overpasses

The size of a crossing depends on many factors, including crossing type, current and future road width, and target species. For overpasses, research in Europe has indicated that bigger is usually better—animal behavior remains closer to normal on wider crossings than on narrower ones. Also, wider, busier roads necessitate wider crossings. Over four-lane highways, crossing width should be greater than 60 meters (~180 ft.), but over two-lane roads, a width of 17 meters (~50 ft.) may suffice.[5]

Underpasses

For underpasses, the size of the crossing limits the animal species that can use it. The size also influences the amount of light in the crossing and the ability for wildlife to see habitat on the other side of the underpass. However, research indicates that the most effective size for culverts is highly species-dependent. A study of the underpasses in Canada's

Banff National Park[6] found that certain species preferred more enclosed passageways and postulated that for prey species, smaller spaces provide comfort and protection against predation. Predatory species, such as coyote and bear, may prefer more open crossings. One solution is to make the crossing as large and open as is feasible, but provide plenty of cover for smaller animals in the form of vegetation and hollow logs or stumps.

Viaducts

The effectiveness of bridges and viaducts as wildlife crossings depends primarily on the length of the span. The longer the span, the greater the area of uninterrupted habitat. For structures over water, effectiveness for terrestrial and amphibious wildlife will be greatly improved if the span is long enough to include a corridor of dry land at the water's edge. In fact, one of the most effective ways to create a wildlife crossing is to extend an existing bridge over dry land to allow movement along the riparian corridor.[7] With many of Oregon's older bridges in need of repair, there are numerous opportunities to create wildlife crossings in conjunction with bridge renovation projects. Viaduct/bridge height can also be a factor when it limits the size of animal that can pass beneath, when it affects the appearance of openness, and when it influences the amount of road noise around the structure.

It's all in the details

Surface materials

Although little formal research has been conducted on the effect of various surface materials on the success of a crossing structure, many sources indicate that surface materials should simulate that of the habitat of the surrounding area.[8] This is especially true in the case of stream culverts. Because traditional culverts can restrict fish passage in many ways, bottomless culverts, which maintain the natural bottom sediment in the stream, are highly recommended. Of course, culverts that span the entire width of the stream, as well as some dry land on the banks, are ideal.

Underpasses and overpasses in Europe almost always use natural surfaces, such as soil, rocks, vegetation and woody debris, rather than manmade materials.[9] Natural surfaces more closely resemble the surrounding habitat and are more likely to provide protective hiding cover for small animals. Natural surfaces may also allow the crossing to vegetate in a way that blends with the surrounding habitat. Because certain species crawl through the interstices between rocks, the size of the substrate is also a factor.[10]

Climatic conditions

Climatic conditions, such as light and moisture levels, are important for some species. It is known that moisture levels can affect the movement of some amphibians, such as salamanders.[11] Many small culverts tend to be dark and do not have adequate moisture to support vegetation. Although little research has been conducted on this topic, sources indicate that maintaining light and moisture levels similar to the surrounding habitat will likely increase the effectiveness of the crossing.[12] Light and vegetation, which affect moisture levels, can be introduced into an underpass through the use of grating or daylighting methods.

"Success is the sum of details."

Harvey S. Firestone
US industrialist

Vegetation

Native plants, shrubs, and trees are widely used to increase crossing effectiveness. Vegetation helps accomplish several objectives when incorporated into the design of a wildlife crossing. It helps create a natural look that simulates the surrounding habitat, it provides important cover for small animals, and it can help attract animals to the crossing. Additionally, plants serve as a barrier to noise and light.

Noise, light, and human activity

Traffic noise and light from headlights can reduce the effectiveness of a crossing. Berms and fencing have been used in Europe and in Banff National Park to dampen traffic sounds and block headlights.[13] Human activity, in general, has a negative impact on the effectiveness of crossings. Certain species, such as cougar and grizzly bear, are particularly repelled by signs and smells of humans.[14] However, crossings that are explicitly designed for both human and animal use are commonplace in Europe and have also been used in the United States. These crossings are used by some animal species[15] and may be a viable option in certain situations, such as urban parks.

Figure 3-5. Vegetation on a wildlife overpass

Fencing and alternative measures

Fencing

Fencing along the roadway is necessary for most wildlife crossing structures to be effective. Fences help guide wildlife to the crossing and they keep animals from going onto the road. It is important that a fencing system be comprehensive and robust, however, because if an animal gets through inadequate fencing, it is essentially trapped on the road and is very vulnerable to traffic. Escape structures, such as one-way gates or earthen ramps, should be included in any fencing system. To discourage animals from crossing the highway at the ends of the fence, extend the fencing beyond the edge of the suitable habitat.[16]

As with the crossing structure, the target species influences fence design. Tall fences, at least 8 ft high, are necessary for species that can jump, such as deer.[17] Finer mesh material may be needed at the base of the fence to keep smaller animals from slipping through. The fencing should ideally be buried underground for several feet so that animals such as badgers and coyotes cannot dig underneath. Even deer can get under

Figure 3-6. Fencing along busy highway

a fence if there is a small gap near the ground. Strands of barbed wire along the top of a fence may discourage animals from climbing the fence.[18] A concrete or metal wall is often used to keep smaller animals, such as amphibians and reptiles, off the roadway. Many amphibians, such as salamanders, can easily climb vertical surfaces, so it is useful to include a horizontal lip on the top of the guide wall.

Figure 3-7. Railing to prevent amphibians from crawling onto the roadway

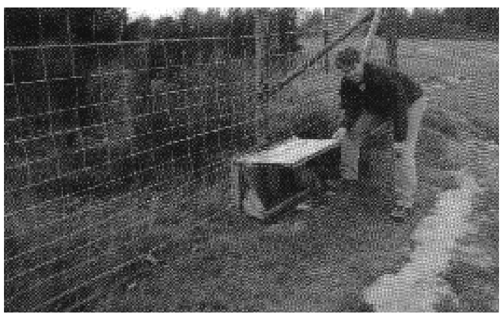


Figure 3-8. Fencing with one-way gate for small animals

While fencing can be an effective way to keep animals off the roadway, on its own fencing is not an adequate response to wildlife mortality or safety concerns. This is because fencing severely inhibits animal movement and heightens habitat fragmentation caused by roads. See page 31 for an example of how fencing along a highway has destroyed a healthy mule deer population in Idaho.

Alternative Measures

Although wildlife crossings have the unique benefits of both improving safety and reconnecting habitat, there are some situations for which a wildlife crossing structure may not be the best solution. If the road in question has low traffic volumes or is not a major connector, perhaps a crossing structure is unnecessary. Speed reduction techniques may suffice, including a lower posted speed limit or speed bumps. Although traditional signage is generally ignored by the driving public, innovative signage, such as seasonal warnings or heat-sensing "smart" signs that flash when an animal is present, are other alternative measures.[19] These techniques can also be used if the project budget does not allow for a wildlife crossing structure.

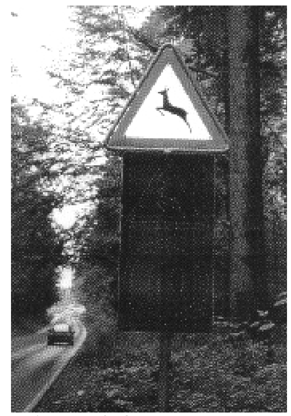


Figure 3-9. Fiber optic speed limit sign

Other strategies that are employed to address wildlife-vehicle conflicts include road lighting, reflectors, olfactory repellents, ultrasound, population control, and habitat modification. Some of these technologies have not yielded a significant reduction in mortality, and none of these strategies address the problem of habitat fragmentation.[20]

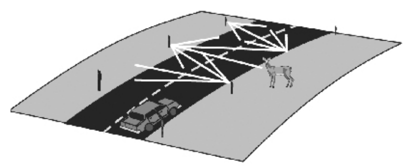


Figure 3-10. Reflectors used for reducing deer mortality

Multipurpose Crossings: Great Idea or Great Mistake?

Is it a good idea to combine a pedestrian or bicycle path with a wildlife crossing? Research conducted by Clevenger and Waltho[21] in Canada's Banff National Park indicates that crossing use by wildlife declines with proximity to human activities such as hiking, bicycling, and horseback riding. Certain species, such as cougar and grizzly bear, are more human-shy than others. Carnivores, in general, seem to be deterred by evidence of humans more so than other animals. Based on these findings, the authors recommend that human use of wildlife crossings be restricted.

However, this analysis is based on a rural example and focuses on large animals that are not generally found in urban environments. Not only is it likely that species residing in an urban setting are not as repelled by signs of human activity, there is evidence that, within a given species, animals in urban settings behave differently than the same species in an undisturbed habitat. For example, peregrine falcons in the wild require a quarter-mile of undisturbed habitat to have a successful hatch.[22] However, a pair of peregrine falcons has been nesting on the Fremont Bridge since 1993, and has successfully raised many young falcons.[23]

Crossings that are explicitly designed for both human and animal use are commonplace in Europe, and have also been used in the United States. For example, a "land bridge" across I-75 in Florida serves wildlife, hikers, cyclists, and equestrians,[24] and an undercrossing along Mission Creek across Highway 93 in Montana is planned for use by both pedestrians and animals.[25] There is evidence that animals do use these multipurpose crossings. Florida's land bridge is already used by opossum and raccoon and is expected to eventually provide passage for deer, fox, and coyote.[26]

A delegation of U.S. transportation and environmental specialists recently visited several European countries to observe and document their use of wildlife crossings. They noted that European multipurpose crossings are used by many or most species and "have proved successful for some wildlife movement."[27]

Another consideration is the availability of federal Recreational Trails Program Fund for pedestrian and bicycle paths. Some jurisdictions may find that combining a wildlife crossing and a human crossing is a good use of resources. Ultimately, a jurisdiction that is considering a multipurpose wildlife crossing in an urban area must review the project goals. The decision will likely hinge on how human-shy the target species is, and whether it is likely to be deterred by human activity.

Figure 3-11. This multipurpose crossing in Florida is already used by raccoon and opossum and will eventually provide passage for deer, fox, and coyote.

Monitoring and Evaluation—An Integral Part of a Crossing Project

While it may be viewed as an afterthought, monitoring and evaluating a crossing to determine its effectiveness is one of the most important stages in a wildlife crossing project. Not only does monitoring help justify the expenditure of funds used to build the crossing, but careful evaluation of a project helps planners of wildlife crossings around the world understand which crossing design types and elements are effective and which are not.

As mentioned earlier in this chapter, the definition of "effectiveness" depends on the goals of the project. Therefore, monitoring and evaluation will also vary based on the project objectives. If driver safety is a high priority, monitoring could involve studying the wildlife-related vehicle collisions before and after installation of the crossing structure. If wildlife mortality is a concern, monitoring could include a survey of the roadkill near the site before and after the crossing structure is built. Finally, if habitat fragmentation is the issue, the number of crossings made by wildlife could be measured.

There are many ways to monitor use of a wildlife crossing structure. Checking for animal tracks is a low-tech, cost-effective option. Sand and ink beds are two common media used for capturing animal tracks. Snow can be used, as well. Other widely used techniques are recording crossing usage via cameras with infrared sensors and detailing the movement of individual animals using radio telemetry.[28]

The most-studied wildlife crossings example is the 24 structures in Banff National Park in Alberta, Canada that span the Trans-Canada Highway. The most recently built crossings have been systematically monitored every three days since their completion in November 1997. Most monitoring has relied upon raked sand track pads for information about species passage, number of animals, and direction of travel. However, cameras with infrared sensors supplement track pad data when tracks are obliterated by inclement weather. In the winter, snowtracking is often used to assess wildlife usage of the crossings.[29]

Researchers have learned important lessons from the Banff monitoring program. First, the necessity for objective, methodical monitoring was demonstrated. Once systematic, comprehensive monitoring was undertaken on all the Banff crossings, research revealed that species believed to be avoiding the crossings were actually using them. The studies also showed that it took several seasons for certain animal species to become acclimated to the crossings, indicating the importance of long-term (three to four year) monitoring.[30]

Figure 3-12. Infrared-triggered cameras are often used to monitor crossing use.

3.2 Cost Considerations

The total cost to build and maintain a wildlife crossing will depend on the type, location, and size of the project. The cost range can be large, even within crossing design types. The most significant cost factor is the size of the crossing, which is project-specific. For example, a small upland culvert built for turtles will be less expensive than a large upland culvert built for bears. This is because the turtle requires much smaller area than the bear, and will require less land (acquisition or easement), building materials, vegetation, and fencing. Maintenance costs tend to be more constant within each crossing type. However, maintenance costs can vary greatly by the type of crossing. Figures 3-13 and 3-14 summarize general statements about the relative construction and maintenance costs of individual design types.

"I suspect from what I saw in Europe you would never be able to come up with a positive benefits/cost ratio because the benefits to the wildlife would be very hard to put a dollar amount on. The Europeans undertake these crossings because they are the 'right' thing to do."

Dave Scott
Vermont Agency of Transportation

Figure 3-13.
Generalized Construction Costs by Design Type

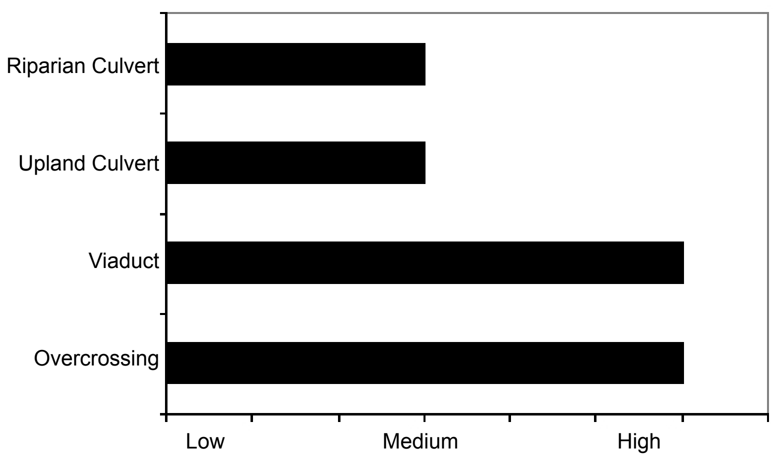
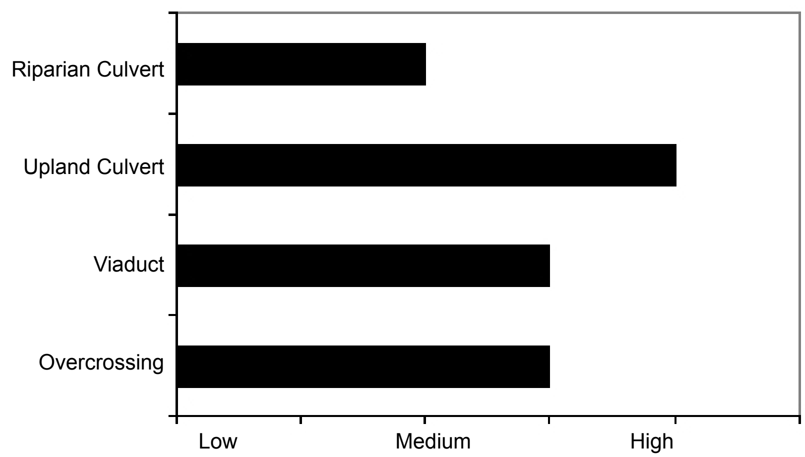


Figure 3-14.
Generalized Maintenance Costs by Design Type



Costs for fencing and alternative measures

Construction considerations:

- Fencing ranges between $8 and $12 per linear foot.[31]
- Wildlife sensing systems are typically inexpensive to install compared to other mitigation measures.

Maintenance considerations:

- Fencing maintenance can be one of the most expensive components of a wildlife crossing system, due to damage from vehicles, falling trees, etc.
- Maintenance and control of vegetation along fences deters wildlife from feeding along the sides of the roadway.
- Wildlife sensing systems become ineffective if not maintained properly.

Cost-saving opportunities

Do it right the first time—If it becomes clear that wildlife will be affected by a new road, find the money to incorporate a crossing into construction of the road. It is a lot more expensive to do a retrofit later. Learn a lesson from planners in Idaho (see sidebar on mule deer along I-84).

Coordinate with other capital improvement projects—Building wildlife crossings can be relatively inexpensive if their installation is incorporated into a road-widening project or other planned improvement.

Extend a bridge—Many Oregon bridges are at the end of their lifespans and are in need of repair or replacement. Repairing or replacing a bridge presents an opportunity to create a wildlife crossing by extending the bridge structure onto the dry land in order to provide terrestrial animals a pathway adjacent to the water.

Expand a culvert—Many culverts in the Portland metropolitan area need to be retrofitted to comply with ESA regulations for fish passage and water flow. Adding shelves or floating docks in the new culvert for terrestrial animals can be done at a relatively low incremental cost.

To build or not to build...

Even in the planning phases of Interstate 84 in southern Idaho, it was known that the highway would bisect the historic migration route of mule deer herds. However, no accommodations were made for the deer when the highway was built, and when it was completed, in 1969, deer mortality skyrocketed.

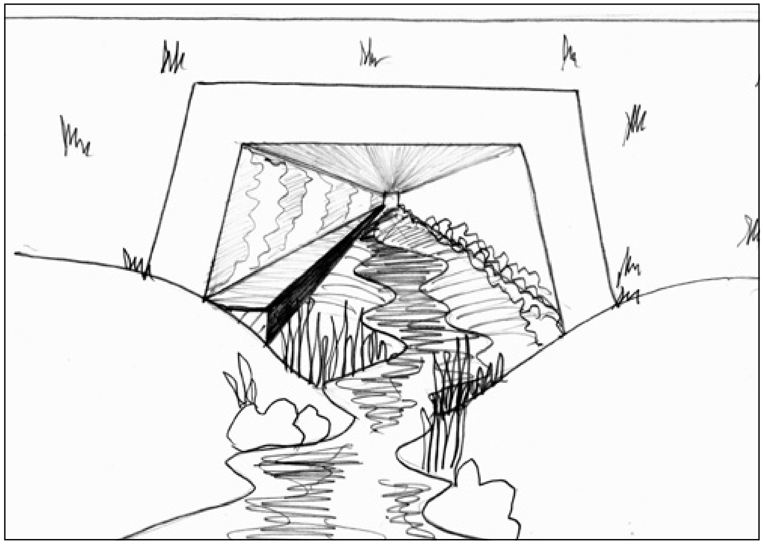
Shortly after the highway was completed, road improvements were constructed, presenting another opportunity to build undercrossings. Yet the crossings were deemed too expensive to build. Instead, cheaper measures such as wildlife reflectors and diversion fences were installed, to little effect. Starvation soon became a problem because the highway kept the deer from reaching their winter feeding grounds, and an extremely expensive feeding program was instituted (A trust fund for the feeding program would have needed $1.3 million in 1982 dollars to feed 1900 deer over 50 years.).

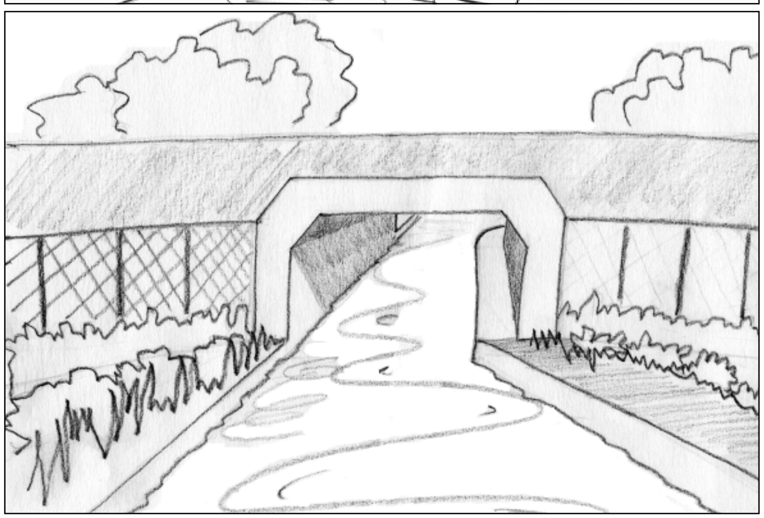
Now, few deer cross the highway, because the herd has lost its memory about how to travel to the winter feeding grounds. By 2001, the herd numbered 1500 animals, down from 4000-5000 deer in the 1960’s.[32]

In the end, the mitigation measures cost more in dollars and wildlife mortality than if the crossings had been constructed from the beginning.

3.3 Design Types

Riparian Culvert





Figures 3-15 (top) and 3-16 (above) show riparian culverts with a shelf for wildlife.

Characteristics

- Crossing built below grade for both water and animal passage.
- Follows a year-round or seasonal stream or waterway.

Advantages

- If modification of an existing culvert to accommodate fish is required by ESA, incorporating accommodations for terrestrial wildlife into the project may be relatively inexpensive.

Disadvantages

- Depending on its size, the culvert can limit the size of animal that can pass through.
- Unless built with ledges, floating docks, or unsubmerged land, riparian culverts discourage usage by terrestrial animals.
- Some animals dislike enclosed spaces.

Comments

- Bottomless culverts are preferable. They preserve the natural substrate that is habitat for some small mammals and amphibians.
- Build the crossing as large as is feasible to accommodate larger animals, but provide cover for smaller animals.
- Incorporate fencing or railing to funnel animals to crossing.

Figure 3-17. Bottomless culvert

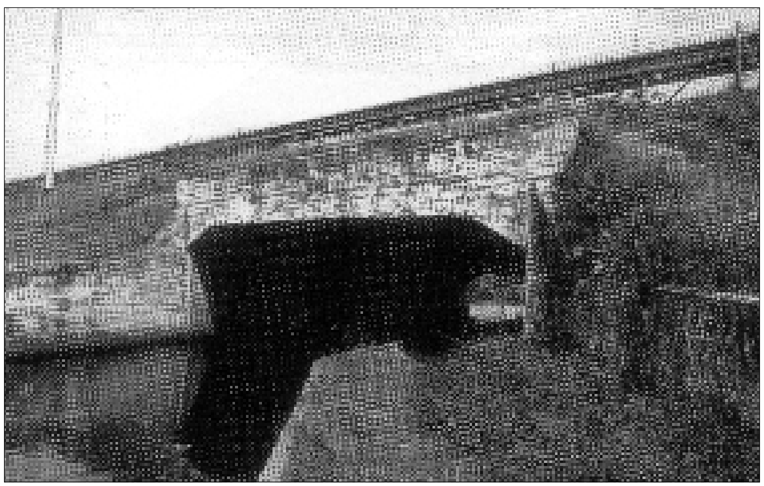


Figure 3-18. Riparian box culvert with modified ledge

Construction considerations

- Riparian culvert projects for wildlife can be combined with fish culvert projects. This provides an opportunity for cost sharing (incremental costs to widen culvert for wildlife are relatively low), and could qualify the project for additional funding sources.
- Streams tend to create ravines, which work as natural corridors for wildlife. This can minimize the planner's need to use fences to channel wildlife movement.
- Examples:
  - *Highway 93, Missoula, MT*—Shelves and ramps were installed in existing culverts to allow passage of small mammals. Total cost: $24,468 (number of culverts unknown).[33]
  - *US 85, Douglas County, CO*—A drainage culvert not originally built for wildlife but used by small mammals was enlarged to a bottomless arch culvert in order to encourage elk usage. Cost: $150,000.[34]

Maintenance considerations

- Certain designs (corrugated) and materials (concrete, metal with protective coatings) for pipe culverts will maximize the life of the culvert and minimize maintenance costs.
- Improper design or placement of the culvert can lead to heightened water velocities and require frequent maintenance because of scour, soil erosion, sedimentation and debris blockage.[35]
- Inappropriate use of culverts by humans may necessitate security measures.

Upland Culvert

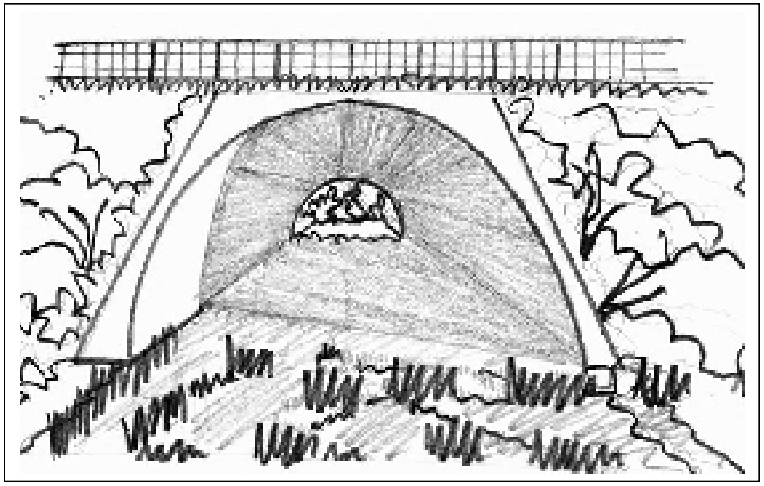


Figure 3-19. Arch culvert (top)
Figure 3-20. Box culvert (above)

Characteristics

- Crossing built below grade for animal passage.
- Upland culverts are built over dry land.

Advantages

- Upland culverts are relatively inexpensive to build.
- Some animals prefer enclosed spaces.

Disadvantages

- Depending on its size, the culvert can limit the size of animal that can pass through.
- Some animals dislike enclosed spaces.

Comments

- Bottomless culverts are preferable. They allow vegetation to grow and some animals are deterred by man-made surfaces.
- Build the crossing as large as is feasible to accommodate larger animals, but provide cover for smaller animals.
- Consider opportunities to daylight the crossing to allow natural light, moisture, and vegetation conditions.
- Incorporate fencing or railing to funnel animals to crossing.

Figure 3-21. Dry bottomless box culvert for small and medium-sized animals

Figure 3-22. Arch culvert with adjoining amphibian railing

Figure 3-23. Pipe culvert primarily for small animals, such as badgers

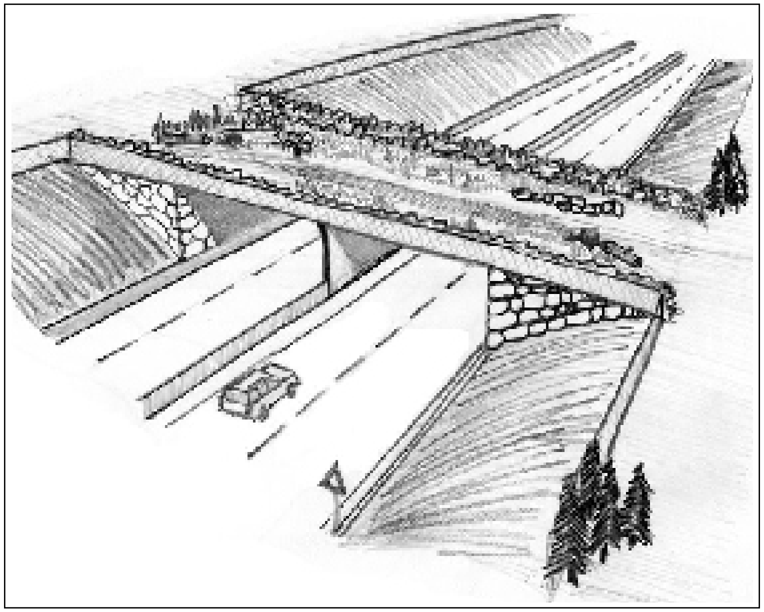
Construction considerations

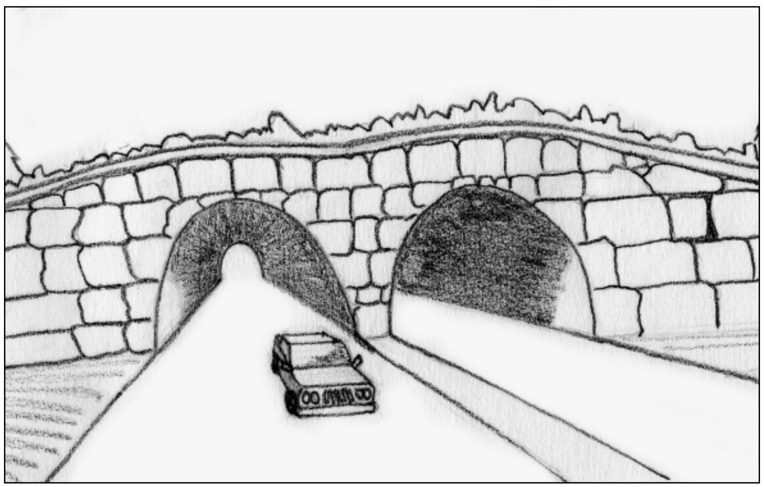
- Upland culvert projects are generally built for specific wildlife use and costs will vary greatly by the size of the target species.
- Dry culverts may or may not be accompanied by a ravine or other change in topography. Less varied topography creates difficulty in channeling wildlife to a below-grade culvert crossing. Encouraging this movement could require (1) raising roadway elevation; (2) depressing adjacent land; or (3) substantial use of fencing. Each of these options carry significant construction costs.
- Examples:
  - *Highway 46, Sanford, FL*—A rectangular, cast-in-place bottomless concrete culvert was built to link suitable black bear habitat. Auxiliary items included chain-link fence, animal crossing signs, and vegetation planting. Construction cost: roughly $1 million.[36]
  - *Highway 1, Banff, Canada*—An elliptical culvert made of prefabricated corrugated steel was constructed for deer, elk, coyotes, and cougars. Total cost: roughly $130,000.[37]

Maintenance considerations

- Upland culverts are often accompanied by fencing, which is easily damaged by automobiles, people, or animals. Fencing maintenance is a substantial cost.
- Upland culverts need to be kept open and accessible, which requires controlling vegetation and disposing of sediment (moved by wind or storm) at the mouth of the culvert. This requires periodic landscape maintenance.

Overpass





Figures 3-24 (top) and Figure 3-25 (above) show overpasses generally designed for larger animals.

Characteristics

- Usually vegetated crossing built over the roadway.

Advantages

- Can be used by animals of all sizes and types.
- Are very effective if wide enough and landscaped with native vegetation.
- Can appear as uninterrupted habitat to animals approaching the crossing.
- Animals who prefer open spaces, such as elk, are more likely to use overpasses.
- In some cases, can be used as a multipurpose path for animals and bicycles/pedestrians.

Disadvantages

- Expensive to build.
- Difficult to build in areas with flat topography.

Comments

- The width of the overpass should increase as road width increases.
- Make sure to provide vegetation, rocks, stumps or hollow logs to provide cover for smaller animals.
- Consider using fencing or vegetation to shield animals from road noise and headlights.
- Some animals are reluctant to use the crossing if it is arched and they cannot see the other side.
- Fencing is usually needed to funnel animals to the crossing.

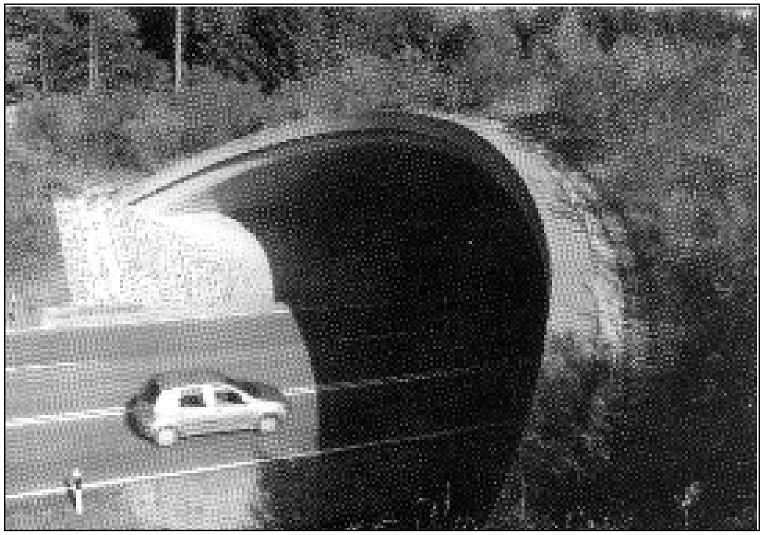


Figure 3-26. Overpass with good vegetation (Switzerland)

Figure 3-27. Overpass connecting habitat (Germany)

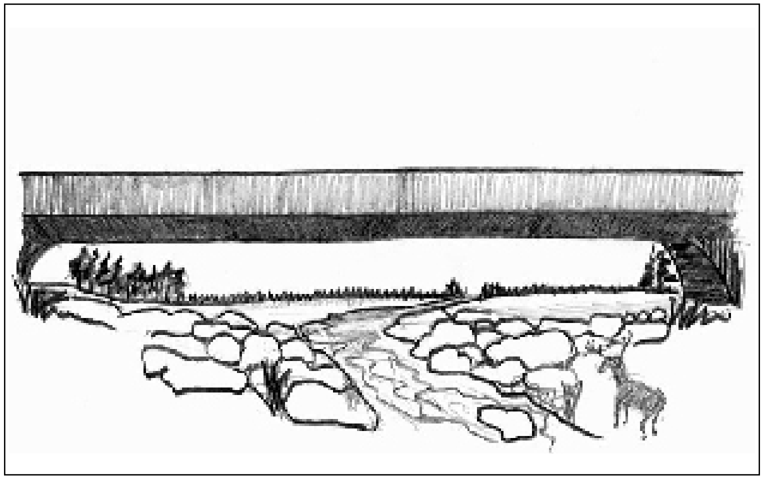
Construction considerations

- Overcrossings have equivalent construction costs to bridges. Design and construction of these structures is very high, due to the costs of the bridge span and pilings.
- There exists potential to combine an overcrossing with a hiking trail or other multipurpose project, depending on the species of interest and their ability to share space with humans. Multipurpose projects could be eligible for federal Recreation Trails Program funding.
- Examples:
  - *I-75, Ocala, FL*—An overpass was built to accommodate small and medium-size mammals and is a multipurpose trail for equestrians. Vegetation absorbs freeway noise and glare. Cost: $3.2 million.[38]
  - *Highway 1, Banff, Canada*—The Wolverine Overpass was constructed in 1997. It is an undivided concrete structure that is also used by deer, elk, grizzly bears, wolves, cougars, and black bears. Cost: $1.3 million.[39]

Maintenance considerations

- Unless topography creates a natural corridor leading to the overcrossing, these structures are typically accompanied by fencing. This adds significant maintenance cost to the project.
- Routine structural inspection is necessary.
- Slope maintenance and stabilization—headwalls, rip-rap, reinforced earth, or vegetation can greatly reduce maintenance frequency.
- Vegetation must be maintained.
- Similar to bridges, overcrossings carry potential for graffiti and vandalism.

Viaduct / Bridge



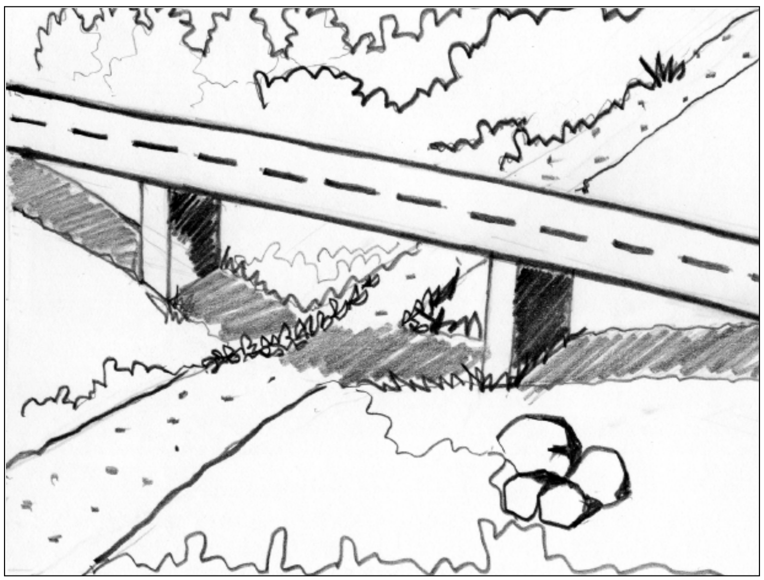


Figure 3-28 (top) and Figure 3-29 (above) show viaducts spanning habitat.

Characteristics

- Elevated roadway that spans water or low-lying land.

Advantages

- If tall enough, animals of all sizes and types can pass underneath.
- Very effective at reducing mortality and connecting habitat.
- Preserves the integrity of the underlying habitat.
- Often built over ravine or stream corridor, which funnels animals through crossing.

Disadvantages

- Expensive to build.
- Difficult to build unless land is low-lying.

Comments

- If spanning water, build the span long enough to include dry land at water's edge.
- Build high enough for all targeted species to pass through and to minimize road noise at ground level.

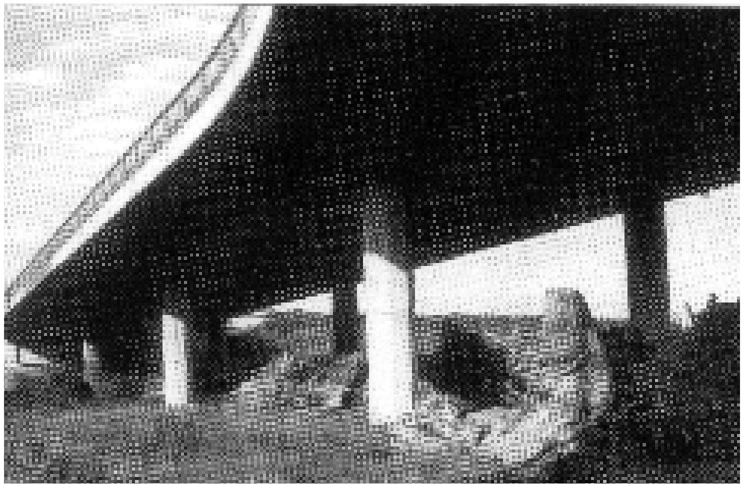


Figure 3-30. Viaduct with stumps for small animal cover (Switzerland)

Figure 3-31. Viaduct with trail underneath used by larger animals (Canada)

Construction considerations

- Viaducts have equivalent construction costs to bridges. Design and construction costs of these structures are very high, due to the costs of the bridge span and pilings.
- Some existing bridges that cross ravines or riparian corridors serve as de facto wildlife viaducts. Bridge retrofit projects could lengthen the bridge span to include dry land for wildlife movement. Potential exists to combine viaduct projects with bridge retrofit projects.
- Examples:
  - *Highway 46, Sanford, FL*—The Wekiva River Bridge was extended 153 feet to allow unsubmerged land for wildlife travel. Construction cost: roughly $433,000 more than bridge would have cost without expanding to accommodate wildlife.[40]
  - *US 85, Douglas County, CO*—Proposed retrofit of an existing single-span bridge to accommodate large mammal movement. Native vegetation will be planted to attract and shield wildlife. Cost: $1.5 million.[41]

Maintenance considerations

- Routine structural inspection is necessary.
- Slope maintenance and stabilization—headwalls, rip-rap, reinforced earth, or vegetation can greatly reduce maintenance frequency.
- Vegetation must be maintained.
- Viaducts carry potential for graffiti and vandalism.

Wildlife Crossing Design Resources

The following resources provide additional information on wildlife crossing designs.

Critter Crossings: Linking Habitat and Reducing Roadkill
(Federal Highway Administration)
http://www.fhwa.dot.gov/environment/wildlifecrossings/main.htm

Wildlife Habitat Connectivity Across European Highways
(Federal Highway Administration)
http://www.international.fhwa.dot.gov/wildlife_web.htm

Wildlife Crossings Toolkit
(USDA Forest Service)
http://www.wildlifecrossings.info/

NCHRP Synthesis 305: Interaction Between Roadways and Wildlife Ecology
(Transportation Research Board)
http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf

Banff National Park's Crossing Structures
(MountainNature.com)
http://www.mountainnature.com/Articles/CrossingStructures.htm

Banff National Park Research Updates, Autumn 1999, Volume 2, Issue 2.
(Highway Service Center – Parks Canada Agency, Transportation in National Parks)
http://www.hsctch-twinning.ca/BNP_ResearchUpdates_article99.htm

Wildlife – Mitigation Measures
(Highway Service Center – Parks Canada Agency, Transportation in National Parks)
http://www.hsctch-twinning.ca/mitigationmeasures1.htm

Forman, R.T.T., et al. (2003). Road Ecology: Science and Solutions. Washington, DC: Island Press.

This page left blank intentionally.

"We are molded, we say, by the conditions and the surroundings in which we live; but too often we forget that the environment is largely what we make it."

Bliss Carman
in Kinship of Nature

4.0 Implementing Wildlife Crossings

4.1 Funding Options

Wildlife crossings address protection and/or restoration of wildlife and fish habitat, water quality, and endangered species. The varied applicability of crossings means that a wide variety of funding options—from federal, state, and private sources—may apply. If a crossing project provides accommodations for sensitive species, it may qualify for funds dedicated for ESA compliance. Or, if a crossing is linked with a hiking trail, it may qualify for recreational trail improvement funds. These examples demonstrate how linking wildlife crossings with other projects improves access to a broad array of funding opportunities. This section highlights just a few of the funding sources that may be available for wildlife crossings, and directs the reader to resources for more information.

Federal programs

Federal funding for many surface transportation programs is provided through the Transportation Equity Act for the 21st Century (TEA-21). This legislation, passed in 1998, allocates funds for a variety of programs related to highways, highway safety, transit, and more. Wildlife crossings may qualify for some of these funds; the specific programs are described below. TEA-21 expires in September 2003, and reauthorization of the bill will likely affect the availability of funding through these programs.

For more information... on TEA-21 and the reauthorization: Federal Highway Administration webpages
http://www.fhwa.dot.gov/tea21/
http://www.fhwa.dot.gov/reauthorization/

Transportation Enhancement

Part of TEA-21, the Transportation Enhancement (TE) program offers federal highway funds for projects that add to the cultural, aesthetic, or environmental value of the transportation system. These "transportation enhancement activities" are contained in four project categories: bicycle/pedestrian safety, scenic or historic highways, landscaping and other scenic beautification, and environmental mitigation. The latter category makes specific provisions for wildlife crossings, including projects that "reduce vehicle-caused wildlife mortality while maintaining habitat connectivity."[1] Many of the projects funded in this category have been focused on wetland restoration and the management of stormwater runoff, but the list of projects also includes a wildlife mortality study, technology for wildlife highway warning systems, and crossings to improve linkages in wildlife corridors.

Transportation projects included in the regional and/or state plan are eligible for these enhancement funds. With the various categories of projects that qualify for TE funds, wildlife crossing projects compete with other proposals. A recent report found that wildlife crossings were not very successful competitors, and that TE money was most often allocated to other types of projects. It also notes that wildlife crossing funding through transportation enhancements may increase as awareness spreads about the importance of wildlife overpasses and underpasses.[2]

Currently, ODOT administers the distribution of all TE funds in the state. This process is completed in two-year cycles.

For more information... on TE funding distribution:
Oregon Department of Transportation
Transportation Enhancement Program Manager
(503) 986-3528.

Figure 4-1.
Recreation trails may be combined with wildlife crossings in appropriate settings.

Recreational Trails Program

These funds are available for a number of purposes, including the development of trail linkages in urban areas, restoration of existing trails, and the acquisition of property and right-of-way for trails. The funds provide an 80 percent federal share, and allow applicants to use other federal funding programs to cover the remaining 20 percent.[3] There is some debate about the effectiveness of multipurpose wildlife crossings, but public parks that host nature trails may be appropriate locations for wildlife crossings. The Recreational Trails Program funds may provide an incentive to explore this option.

For more information... on Recreational Trails funding:
Oregon Parks and Recreation Department
State Trails Coordinator
(503) 378-4168

Hazard Elimination Program

The Hazard Elimination Program (HEP) funds are used for safety improvement projects that address existing safety problems and cost less than $500,000. They must also meet cost-benefit ratio standards, and the amount allocated to counties varies because projects are funded on a competitive basis. ODOT distributes the money and selects projects.[4] Wildlife crossing projects that improve safety by reducing the potential for wildlife-vehicle conflicts may be eligible for these funds.

For more information... on Hazard Elimination Program:
Oregon Department of Transportation
Traffic Management Section
(503) 986-3568

State Programs
Statewide Transportation Improvement Programs (STIP)—Road Modernization Funds

ODOT appropriates funding for the design, engineering, construction, and preservation of projects through the STIP process.

Highway Bridge Replacement and Rehabilitation

Bridges are defined by the National Bridge Inventory as any crossing structure that is 20 ft. or longer. The Oregon inventory of bridges includes crossings longer than 6 ft. The Oregon Department of Transportation estimates that 350 of the state's bridges are nearing the end of their 50 years of planned use, and 1,000 bridges are vulnerable to earthquakes. The state estimates that $3.8 billion will be required to make the necessary repairs; the Oregon Transportation Investment Act

Figure 4-2.
Rendering (photo-enhanced image) of bridge improvement

has allocated $127 million.[5] While funding for these repairs is limited, many bridges will be retrofitted. This presents an opportunity to integrate wildlife crossings into bridge retrofit designs because the incremental cost of adding facilities for safe wildlife passage is relatively low.

Fish Passage Programs

The State of Oregon has conducted a statewide culvert inventory to assess the problem of inadequate fish passage in the state's waterways. ODOT has begun replacing identified problematic culverts.[6] The low incremental cost associated with adding accomodations for wildlife to fish passage improvements may provide opportunities for incorporating a wildlife crossing into a culvert enhancement project.

Figure 4-3. Inspecting a dry-land shelf integrated into a riparian culvert

Bicycle / Pedestrian Facilities

The State of Oregon requires that "reasonable amounts" of State Highway funds be directed to facilities for bicycle and pedestrian travel.[7] Walkways and bikeways that combine wildlife passage may help satisfy this requirement and provide a cost-sharing opportunity.

For more information... on road modernization programs or how to participate in upcoming processes for input:
Oregon Department of Transportation, Region 1,
State Transportation Improvement Program Coordinator
(503) 731-8279

Regional Programs

In the Portland metropolitan region, most federal and state funds are channeled through Metro, the regional Metropolitan Planning Organization (MPO), where local government representatives allocate funds based on regional needs. Metro funding is allocated through the MTIP. The MTIP is a multiyear intermodal program of transportation projects that is consistent with the metropolitan transportation plan. The MTIP offers an opportunity to incorporate a wildlife crossing into current or upcoming transportation projects. A regional assessment to identify candidate locations for crossings should be conducted, and identified locations should then be integrated into current and upcoming MTIP projects.

For more information... on MTIP or how to participate in upcoming processes for input:
Metro, Transportation Planning
(503) 797-1757
http://www.metro-region.org/pssp.cfm?ProgServID=2

For more information...

The following websites provide funding information and links to programs that provide money for wildlife protection, fish passage, and habitat restoration projects.

Fisheries Restoration and Irrigation Mitigation Program
Fish screening and passage grant program
http://www.4sos.org/wssupport/group_support/funding.asp

Oregon Watershed Enhancement Board
Types of Assistance
http://www.oweb.state.or.us/directory/assistance.html

U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds
Where Can I Get Funding to Start a Wetland Project?
http://www.epa.gov/owow/wetlands/facts/funding.pdf

4.2 Capital Improvement Plans

Local jurisdictions prioritize new projects and retrofits or improvements in the Capital Improvement Plan (CIP). Project funding is allocated based on this priority list. CIPs represent a five-year planning horizon and are reviewed periodically to account for changing conditions. Ideally, wildlife crossings would be included in the original project proposal. However, the CIP review offers another opportunity to incorporate a wildlife crossing into an existing transportation project.

4.3 The Regulatory Landscape

Numerous federal, state, and local regulations guide the development of roadway projects. Rather than presenting additional regulatory challenges, wildlife crossings may be a way to provide the environmental mitigation measures required by many of these policies.

The following list provides brief explanations of how wildlife crossings may be uniquely affected by federal, state, and local regulations.[i]

Federal

Clean Water Act—Requires a permit process designed to protect wetland and aquatic habitats by requiring disclosure of expected development impacts. The permit may be required if construction of the wildlife crossing facility will affect a wetland or waterway. At the same time, wildlife crossings may be a way to help a project pass the permit process if the project is expected to create substantial negative impacts on a wetland or aquatic habitat.

National Environmental Policy Act (NEPA)—This policy triggers the Environmental Impact Statement (EIS) or Environmental Assessment (EA). Wildlife crossings may be a way to lower the measured environmental impact of a road project and meet the obligations of NEPA.

---

[i] Information on these regulations taken from *Green Streets* (Metro, 2002).

Endangered Species Act (ESA)—Projects that impact "proposed, threatened or endangered species and/or designated critical habitats" may be required to comply with this permit process. The application for Section 10 of the ESA requires a habitat conservation plan. Wildlife crossings may be an effective element of a plan designed to protect sensitive species.

Figure 4-4. Stair-step passage for fish mobility

State

Removal-fill permit—Applies to projects that propose to fill in a certain amount of wetland material, or projects that will affect salmon habitat. Permits may be granted in some cases, although they can be difficult to obtain. Bridges and other infrastructure that allow for fish passage and wildlife crossings might help avoid this requirement or increase chances of obtaining the permit.

Crossing/encroachment permit—ODOT requires a permit for projects that cross or encroach upon State property. A wildlife crossing facility that would extend into State-owned land would probably require this permit.

Local

Land use requirements—A wildlife crossing that occurs entirely within the right-of-way would not be held to land use requirements. It might be necessary to obtain a variance if the facility extended beyond the public right-of-way.

Local transportation engineering/traffic control—Local approval may be required if the wildlife crossing impacts local transportation corridors. Planners should consult with local traffic engineers to ensure that the crossing facility complies with the American Association of State Highway and Transportation Officials (AASHTO) guidelines for the roadway.

Private

Crossings that impact private property may require a permit or approval. It may be useful to pursue an easement or acquire property to ensure that animals will be able to access the crossing, even on private property.

4.4 Road Design Classifications

Earlier sections of this guidebook describe a number of factors critical to building a successful wildlife crossing. However, some consideration should also be given to the design classification of the roadway being traversed by the crossing. The type of roadway determines which agencies should be involved in the planning process, what funding sources can be explored, what permits might be triggered, and which engineering guidelines need to be addressed.

Road design classifications are also very important for the incorporation of retrofitting projects with Metro's MTIP. All projects in the MTIP should be classified according to Metro's road design classifications.

Any wildlife crossing projects being built on a road considered "substandard" (not meeting design classification standards) will need to be made long and wide enough so that it meets future road widening dimensions. The Pleasant Valley opportunity site example described in Chapter 6 provides an example.

Consult the *Green Streets* handbook and local plans, including the Regional Transportation Plan, to determine the design classification of the road being considered for a wildlife crossing before design occurs.

For more information...

Green Streets and Livable Streets programs
Metro
(503) 797-1839
http://www.metro-region.org/
e-mail 2040@metro-region.org

Regional Transportation Plan
Metro
Metro's transportation hotline: (503) 797-1900
http://www.metro-region.org/
e-mail trans@metro.dst.or.us.

This page left blank intentionally.

1. *Is there a need for a wildlife crossing?*

2. *What are the goals of the wildlife crossing project? How will the success of the crossing structure be measured?*

3. *Is a wildlife crossing viable and appropriate in this location?*

4. *What crossing design would be most effective?*

5. *What implementation issues might affect the project?*

5.0 Putting It Together

How do you know if a wildlife crossing is right for your project? If a crossing is appropriate, what should you do next? This section addresses five questions (listed on the facing page) that face planners. It also summarizes the key pieces of information provided throughout the guidebook and categorizes information to assist planners in exploring a wildlife crossing at a specific location. The steps outlined here were used to research and develop recommendations for the three opportunity sites identified in Chapter 6. A site assessment guide developed through this process is also included as Appendix C.

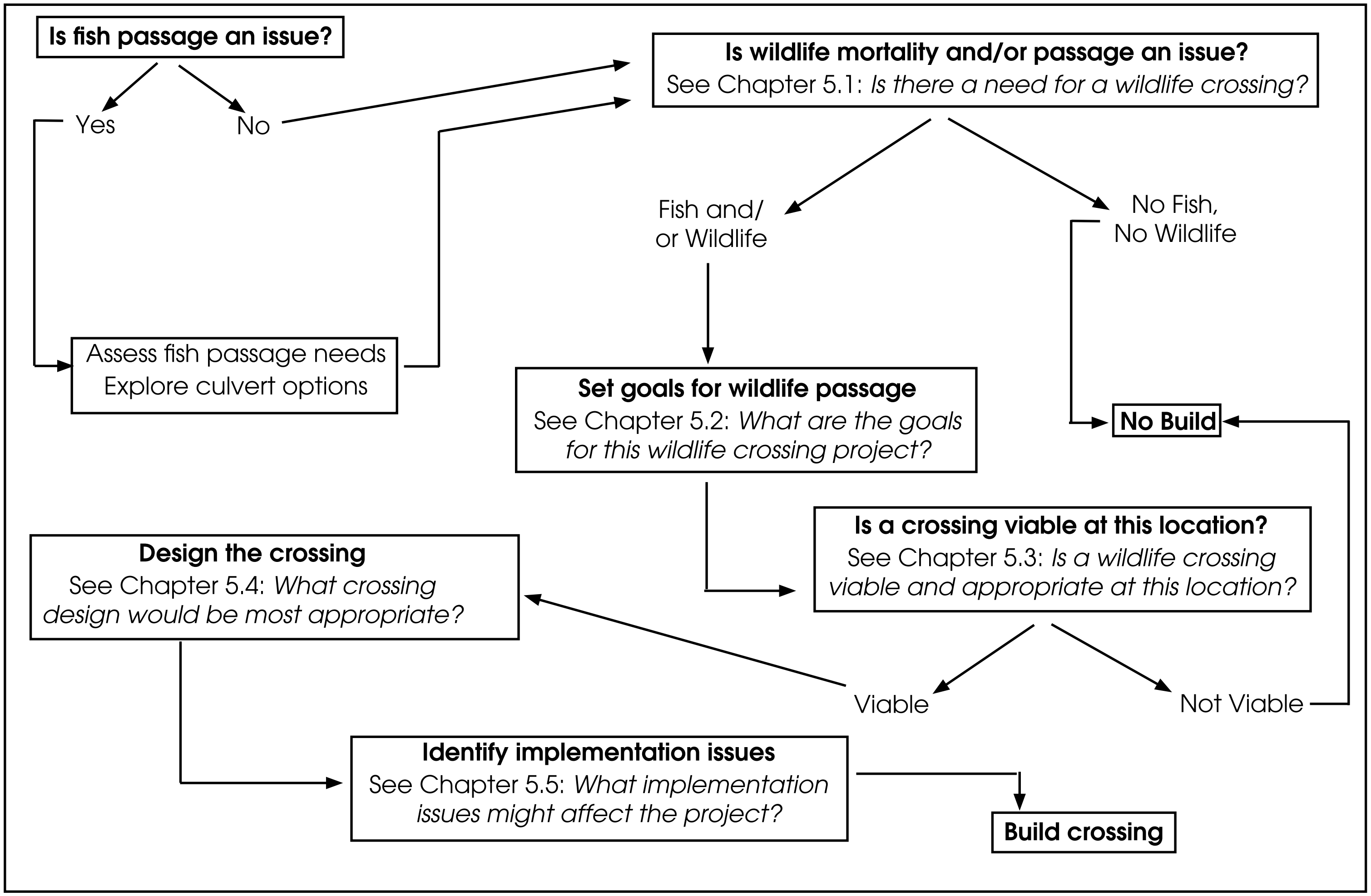


Figure 5-1. Process for Planning a Wildlife Crossing

☑ Question 1. Is there a need for a wildlife crossing?

There are three common scenarios in which a planner might consider the need for a wildlife crossing. The first is when a jurisdiction is planning a new road in an area with known or suspected wildlife habitat. The second scenario could be when a jurisdiction is planning a road modification project (retrofit), and there is a history of wildlife-vehicle conflicts or other negative impacts on the surrounding wildlife and habitat. The third scenario could be when negative impacts of development on wildlife are driving the interest in the retrofit project.

Under any of these scenarios, it is necessary to gauge the extent of the problem before moving forward with a wildlife crossing plan or design. Understanding the safety and wildlife impact issues are critical for this problem assessment. The following three questions will help define the need for a crossing at a specific location.

☑ Is there a history of wildlife-vehicle conflicts near the potential crossing site?

This analysis will be especially appropriate if transportation infrastructure already exists at the site and the proposed project is a retrofit of this infrastructure. A history of wildlife-vehicle conflicts may indicate a safety problem.

Resource

Oregon Department of Transportation
Crash Analysis and Reporting Unit
www.odot.state.or.us/tdb/accident_data
(503) 986-4240

☑ Is there a history of road-related wildlife mortality near the potential site?

The ability to answer this question is limited by the data available in each jurisdiction. Metro has compiled deer/elk mortality data for the region starting in 1992 (see Chapter 2). Additionally, other sources may be able to provide quantitative or anecdotal assessments of the problem, such as county animal control departments, parks services, road maintenance departments, property owners, and the Audubon Society of Portland.

Resources

Metro Data Resource Center
(503) 797-1742, *www.metro-region.org*

Audubon Society of Portland,
(503) 292-6855, *www.audubonportland.org*

☑ Is the crossing located within a wildlife movement corridor?

Sufficient data to identify wildlife movement corridors may not be available on a consistent basis throughout the metro region. Ultimately, it may be appropriate to assign a wildlife biologist to identify "hot spots" and corridors as per Appendix A. However, there are several sources to check for "off-the-shelf" information before commissioning a study. The first step would be to check local plans. Some communities, such as Pleasant Valley, have developed habitat linkages maps as part of a larger comprehensive planning effort. If these data are not available, contact Metro's Regional Parks and Greenspaces Department. Metro has developed a preliminary map of wildlife movement corridors for the region, based on known wildlife habitat and movement and location of riparian corridors. Finally, use of Metro's Regional Land Information System (RLIS) data to assess riparian corridors and vegetation in the crossing's vicinity can be a telling indicator of wildlife movement corridors. As mentioned in Chapter 2, 93 percent of the species in the Portland region use riparian habitat for breeding or feeding.

Resources

Pleasant Valley Concept Plan
City of Gresham, Community and Economic Development Department
http://www.ci.gresham.or.us/departments/cedd/

Metro Regional Parks and Greenspaces Department
(503) 797-1849

Metro Data Resource Center
(503) 797-1742

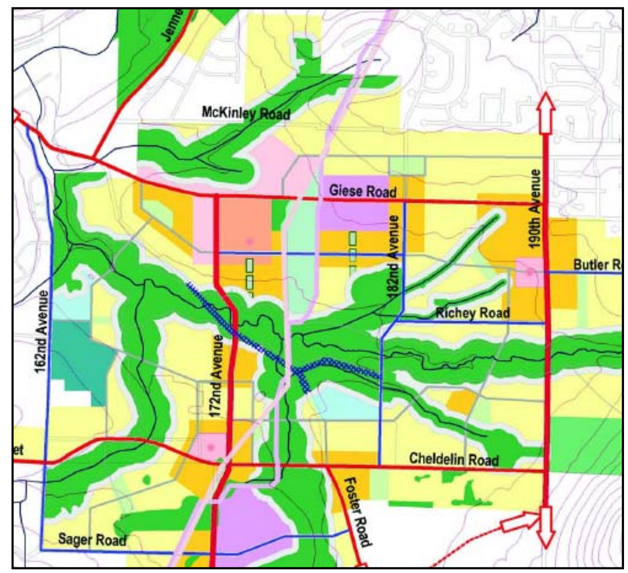


Figure 5-2. The Pleasant Valley Concept Plan includes plans for maintaining the integrity of the natural environment as well as growth.

☑ Question 2. What are the goals of the wildlife crossing project? How will the success of the crossing structure be measured?

The type, size, and location of the wildlife crossing will depend on several factors, many of which are tied into the original objectives of the project. Some questions intended to highlight the relevant issues include:

- Is it important to restore or maintain habitat connectivity, or is the primary goal to reduce road mortality and increase safety for humans?
- Is the crossing intended for a wide variety of species, or is just one sensitive species targeted? To request a species list for the project vicinity, contact Metro Natural Resource Planning at (503) 797-1839.
- Is maintaining the current speed and mobility of the existing roadway critical, or are speed reduction techniques an option?
- Does the benefit of combining the wildlife crossing with a bicycle/pedestrian trail outweigh the possibility of reduced animal use due to presence of humans? Does the species list for the project vicinity include human-shy wildlife?
- What is the project budget?

The project objectives will also provide a way to measure the success or effectiveness of the project. Figure 5-3 suggests a few methods for evaluating effectiveness.

Figure 5-3. Evaluating Crossing Effectiveness

Objective	Evaluation Technique
Increasing safety	Number of wildlife-vehicle conflicts
Decreasing animal mortality	Amount of wildlife mortality
Restore or maintain habitat connectivity	Number of road crossings by different species

Whatever the measure for evaluating effectiveness, monitoring is an important element of any crossing design. Monitoring of early crossing design projects will be essential for refining the process and improving overall effectiveness for future crossings. Collaborating with academic researchers could help defray some of the costs associated with monitoring programs.

☑ Question 3. Is a wildlife crossing viable and appropriate at this location?

The land use adjacent to or near the site could lend itself to the long-term protection of wildlife habitat. On the other hand, residential or commercial development in the vicinity could negate the effectiveness of the crossing. It is important to site a crossing in a location where one would want to preserve habitat connectivity.

☑ What are the vehicle mobility considerations at the site?

If the road is rarely traveled, or the speed limit is low, the crossing may not be necessary and alternative measures such as speed bumps may be appropriate. At the same time, high projected future traffic volumes or speeds may indicate the need for a grade-separated crossing for wildlife. In the case of an existing road, traffic volume and count data are available from the individual jurisdiction and from Metro's Data Resource Center. When in the field, it is also advisable to check the posted speed limit at the site and compare it to the actual speeds of vehicle travel on the roadway.

☑ What are the adjacent land uses and zoning?

It is important to check existing and planned uses for adjacent properties. Land that is forested and publicly owned, for example, may be conducive to habitat protection. Land that is currently vacant but planned for housing or commercial development is probably not. The acquisition of property or conservation easements might help ensure the viability of habitat in the vicinity of the crossing and wildlife access to the facility.

☑ What is the quality of the habitat?

Does the site contain habitat worth protecting? What is the quality of the vegetation? What are the water features? Metro's Wildlife Habitat Assessment Narrative Sheet (available from the Natural Resource Planning Department) is a good resource for determining habitat quality. It may be appropriate to consult with a biologist to determine habitat quality.

Figure 5-4. The land uses shown in this picture make this location inappropriate for a wildlife crossing.

Resources

Metro Data Resource Center
(503) 797-1742

Metro Natural Resources Planning
(503) 797-1839

☑ Question 4. What crossing design would be most appropriate?

Given the project goals, the targeted species, and site characteristics such as topography, what crossing design would be most effective? Consultation with a biologist and/or engineer may be necessary to determine the most appropriate crossing design. However, the following questions will help with preliminary design solution considerations, based on a number of possible project goals.

☑ What are the targeted species?

The size of the animal will, in part, determine the size of the crossing. Different animals prefer different crossing environments. For example, some animals prefer open expanses, while others like to feel hidden. Some animals will go out of their way to avoid using an undercrossing. Amphibians may only use crossings with high moisture levels. Consult a wildlife biologist or animal behavior specialist to determine the preferences of your species of interest.

☑ Is there water at the site?

If there is water at the site, a riparian culvert or a viaduct would be an appropriate design. Either of these options will allow free passage of water and fish. The inclusion of dry land on one or both sides of a viaduct will accommodate wildlife movement. Riparian culverts could include dry land, a shelf, or a floating dock for wildlife on one or both sides of the stream.

☑ Are there topographical considerations?

Certain topographies lend themselves to specific designs. For example, viaducts are a good solution over a steep ravine or body of water. Consult an engineer to determine the feasibility of different designs given the site topography.

Figure 5-5. This small, daylighted crossing takes into account an amphibian's need for moisture.

Figure 5-6. Signage warns drivers of an upcoming salamander crossing in Amherst, MA.

Figure 5-7. Potential Design Solutions Depend on Project Goals

Project Goal	Potential Design Solution
1. Restore or maintain habitat connectivity	The crossing should be constructed so that it can serve as many species as possible. Build the crossing as large as feasible, given cost constraints.
2. Reduce road mortality and increase safety for drivers	Any crossing structure will help reduce the number of animals on the road, if it is accompanied by a comprehensive, robust fencing system. Build a 15 ft. tall, opaque fence and bury wire mesh several feet below ground. Install concrete barriers for smaller animals, and build in escape mechanisms, such as ramps, so that animals caught on the road can escape.
3. Encourage a wide variety of species to cross roadway	The crossing should provide inviting habitat for animals in all habitat niches. Therefore, make the crossing as wide and open as is feasible, but provide cover for smaller animals. Plant native vegetation in and around the crossing. Use native substrate. If it is a culvert, give strong priority to a bottomless culvert option. Some European countries go so far as to build ponds on their green bridges to attract water-loving animals.
4. Encourage just one target species to cross roadway	The appropriate crossing design depends on the particular species. See "What are the targeted species?" under question four for further discussion.
5. Maintain the current speed and mobility of the existing roadway	An overcrossing or undercrossing may be appropriate for this situation. In certain situations, speed bumps or signage may be sufficient to reduce road mortality.
6. Ensure that the crossing is well-used by human-shy animals	Building a multipurpose wildlife and human crossing is probably not appropriate. Use vegetation and fencing to shield animals from road noise and headlights.

☑ Question 5. What implementation issues might affect the project?

There are a number of funding and regulatory issues that may provide opportunities and constraints for the wildlife crossing project. Some of these are listed below.

☑ Does the site affect a wetland?

If the crossing site or crossing is near a wetland, there are more opportunities than constraints. Money may be available if the crossing serves as mitigation, and a crossing as mitigation may also help a roadway project comply with certain environmental regulations. As with any project sited near a wetland, the wildlife crossing must avoid negatively impacting the quality of the wetland and must replace any wetland acreage filled as part of the crossing project.

☑ Will the wildlife crossing facility be located on public property, or will it extend into private property?

If the crossing infrastructure is located entirely within the existing road footprint (e.g., does not extend beyond the area owned and managed by the public agency), it is not likely to trigger any land use processes that would restrict the project from moving forward. However, if the crossing extends into private property, it will be necessary to pursue an easement or property acquisition from the property owner. This may impact project cost and schedule.

☑ Will the crossing lower vehicle-related wildlife mortality, improve safety, or maintain or improve habitat connectivity?

Projects that achieve these objectives may qualify for Transportation Enhancement funds. See Chapter 4 for more information.

☑ Can crossing construction be integrated into another type of project?

State funding for bridge repairs, local capital improvement plans, and fish culvert retrofits are a few scenarios where other construction efforts might provide cost-sharing opportunities. Opportunities also exist if the crossing is combined with bicycle/pedestrian facilities and/or recreational trails. Beware that some animal species are human-shy and will avoid crossings that have evidence of human activity (see Multipurpose Crossings, Chapter 3).

Figure 5-8. This overcrossing across I-75 in Florida was designed to serve wildlife and recreational users.

This page left blank intentionally.

"To improve the golden moment of opportunity, and catch the good that is within our reach, is the great art of life."

Samuel Johnson

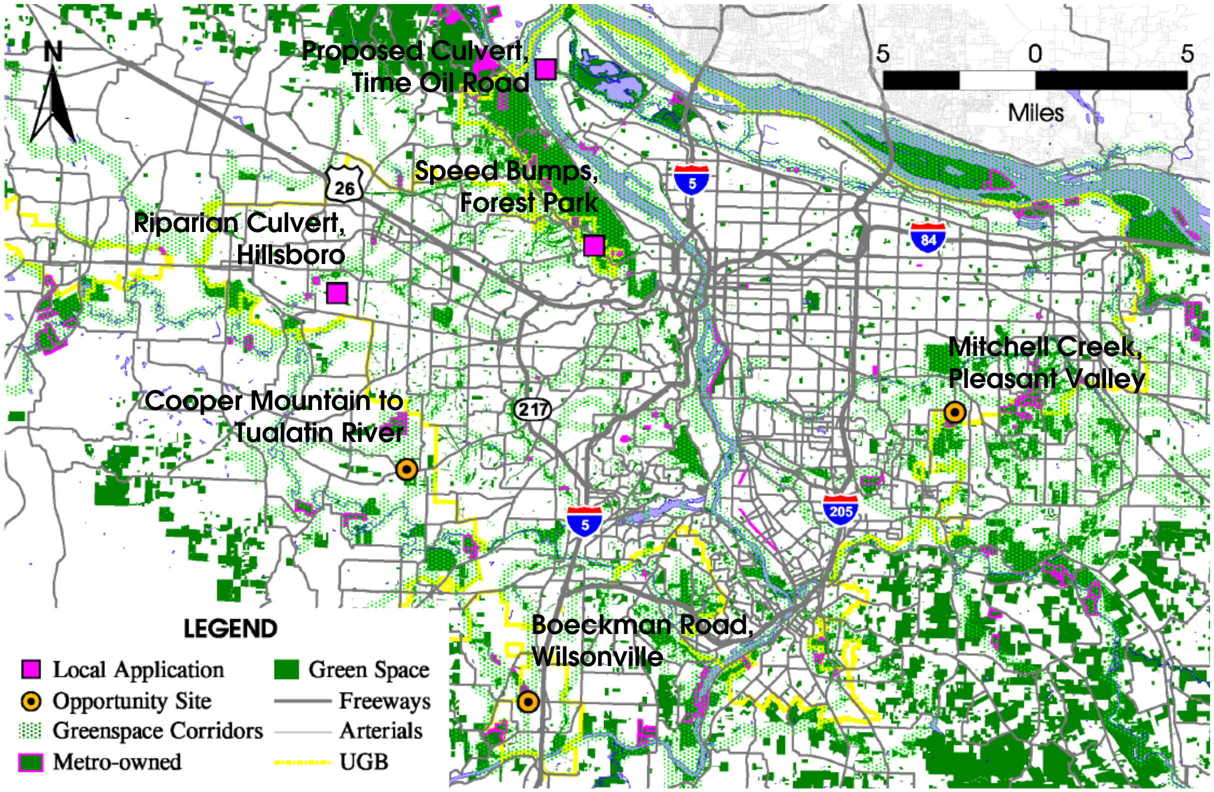
18th Century writer

6.0 Local Applications and Opportunity Sites

6.1 Introduction

The Portland region presents great possibilities for improving safety and connecting wildlife habitat through the planning and construction of wildlife crossings. This section highlights that potential through a description of three existing crossing projects in Forest Park, the City of Hillsboro, and on property owned by the Port of Portland (see Figure 6-1). The chapter also includes three opportunity sites that demonstrate how and under what circumstances future projects may be developed. These locations were selected and analyzed using the information provided in the guidebook, and followed the process described in Chapter 5. Each opportunity site analysis provides a description of the problem and a recommended design concept.

Figure 6-1. Local applications and possible opportunity sites in the Portland metropolitan region



Where is the Best Place in the Region to Locate a Crossing?

With limited funding available for mitigating the impact roads have on wildlife, it may seem that identifying the place in the region most in need of a crossing would be the best way to site a crossing. However, finding that location is a difficult task. Since wildlife crossings come in different types and sizes and can serve various purposes, there is no one specific method for determining the most effective location in the region to site a new wildlife crossing. One approach is a comprehensive regional assessment of the need for wildlife crossings, prioritizing sites based on data such as:

- Location of greenspaces around the region and potential linkages between them
- Location of habitat for a specific threatened species
- Occurrence and magnitude of wildlife mortality
- History of wildlife-vehicle conflicts
- Proximity to wildlife movement corridors
- Existence of high quality habitat divided by road
- Proximity to riparian corridors
- Existence of culvert needing retrofit for fish passage
- Functional classification of road
- Speed limit and level of traffic
- Planned road improvement or other projects
- Current and future land use
- Topography
- Other considerations, such as potential traffic generators

Such a regional assessment is strongly recommended because it helps a region define its goals and priorities, raises awareness about the need for wildlife crossings in the region, and lays the groundwork for integrating crossings into future transportation projects. However, while it is important to go through the process of conducting an assessment of the region and establishing priorities, the actual construction of crossings may occur differently. An element of opportunism is involved.

Selecting an optimal location for a wildlife crossing is similar to siting other infrastructure improvement projects—while the need for physical improvements may be great, the resources for providing improvements are often scarce. Because there are likely to be many locations where a wildlife crossing would be valuable, and because funding for wildlife mitigation tends to be available on a project-by-project basis, it may be necessary, and perhaps most efficient, for each jurisdiction to take advantage of unique opportunities as they arise. By capitalizing on cost-sharing opportunities with urban road projects, wildlife crossings can become an integral component of roadway design and a viable option for improving roadway safety and reconnecting urban wildlife habitat.

6.2 Local Applications

Riparian Culvert with Wildlife Shelf[1]

City of Hillsboro, OR

The City of Hillsboro recently constructed two concrete box culverts with shelves to accommodate reptiles, amphibians, and small mammals. These culverts, which connect Reedville Creek under SW 234th Avenue and SW Frances Street, are roughly 8 ft. wide and 10 ft. high (see Figures 6-2 and 6-3). The project included construction of simulated stream bottom of soil and rock. The City ordered extra soil and rock to make the wildlife shelves, which are banked on one side of the stream. The shelves were built to be roughly 1-1½ ft. wide and 1 ft. above the ordinary high water elevation.

The idea for a wildlife shelf at this location came from the Oregon Department of Fish and Wildlife (ODFW), and was based on the known existence of small mammals and reptiles in the vicinity of the creek. According to Jim Grimes of the ODFW, many culverts with wildlife shelves have been constructed in the region over the past few years. The State is pursuing additional projects to allow wildlife passage through stream crossing culverts in areas where road densities are high and roads fragment valuable wildlife habitat.

The culverts were built as part of a larger road project to connect SW 234th Avenue with SW Frances Street, and cost roughly $800/linear-foot to construct. The total cost of the two culverts, including the simulated stream bottom, was $152,000. The effectiveness of this project is not yet known. One observed criticism is that the shelves are sometimes immersed in water due to fluctuations in stream depth, which will likely discourage small mammal usage.

Figure 6-2. The City of Hillsboro used extra soil and rocks to build up a shelf for wildlife on the side of the culvert.

Figure 6-3. The northwest culvert abuts a park, which contains some protected riparian habitat.

Speed Bumps along Cornell Road[2]

Forest Park, Portland, OR

Forest Park is one of Portland's wildest natural areas. Cornell Road is a well-used road that runs through the southeast portion of Forest Park, connecting downtown and Northwest Portland with residential areas to the southwest. As a major connector road for commuters, Cornell Road experiences high volumes of traffic during peak hours. Wildlife mortality was an ongoing problem on the road until speed bumps were installed in 1999.

For many years Bob Sallinger, director of the Portland Audubon Society's Wildlife Care Center (located on Cornell Road), picked up injured and deceased wildlife he found along this busy stretch of road on his way to and from work. He remembers that there was a period during which he picked up a downed animal almost every week. After years of unanswered requests for traffic calming measures, the Portland Office of Transportation finally installed several speed bumps.

Since that time, Sallinger has observed a substantial reduction in wildlife mortality along this segment of Cornell Road. This suggests that the reduction in automobile speeds achieved by installing speed bumps can significantly improve opportunities for wildlife movement and help mitigate the barrier effects of roads.

Figure 6-4. Speed bumps on Cornell Road in Forest Park helped reduce wildlife mortality near the Audubon Society.

Figure 6-5. Speed bump on Cornell Road near Balch Creek

Proposed Small Animal Culvert[3]

Time Oil Wetland Complex, Port of Portland

The proposed underpass will be located in the Time Oil Wetland complex in the Port of Portland's South Rivergate Industrial District. A transportation corridor containing Time Oil Road, a railroad complex with two spur lines, and two access roads divides the wetland complex. Wildlife researchers observed frequent movement of animals across the transportation corridor. A need for additional wildlife mitigation measures was identified to address increasing development and the resulting traffic on Time Oil Road.

The project objectives are to minimize mortality of reptiles, amphibians, and small mammals on Time Oil Road and to improve habitat connectivity between the wetlands. The Port of Portland evaluated a number of options that included a no-action alternative, closure of Time Oil Road, signage, undercrossings, overcrossings, and gated crossings. The preferred option was a culvert undercrossing with guide walls—metal or concrete curbs that funnel small animals toward the crossing—and appropriate vegetation.

If implemented, the project will be monitored for a minimum period of five years as part of the Port of Portland's Environmental Enhancement Program. The estimated total cost of the project is $371,500, and the installation would be timed to coincide with improvements to Time Oil Road. Authorization to develop the project is expected in the summer of 2003.

Figure 6-6. Looking west from Time Oil Road

Figure 6-8. The undercrossing will connect wetlands divided by Time Oil Road.

Figure 6-7. Time Oil Road, looking south

Cooper Mountain-Tualatin River

Cooper Mountain-Tualatin River Connection

Metro owns 247 acres of significant forested habitat on the southwest slope of Cooper Mountain. This preserve, which is home to many species of plants and animals, is about 2.5 miles from the Tualatin River, an important riparian corridor. The connection between the upland habitat of Cooper Mountain and the riparian habitat of the Tualatin River is critical to restore, as many species depend on both types of habitat to complete their lifecycle. Scholls Ferry Road (State Highway 210) is a busy arterial and is the only major road barrier in this regionally significant wildlife corridor. Metro's deer/elk incident survey revealed many deer kills along this stretch of Scholls Ferry Road.

Figure 6-9. Culvert as seen from north side of Scholls Ferry Road

Figure 6-10. Stream ravine and habitat on north side of Scholls Ferry Road

Location

- Washington County, OR
- One mile west of Tigard and Beaverton on Scholls Ferry Road
- Between Metro-owned open space on Cooper Mountain to the north and the Tualatin River to the south

Topography

- Topography at parcel owned by Metro is too flat—not conducive to crossing
- Ravine with stream runs through adjacent parcel to west
- Ravine facilitates construction of box culvert
- Existing culvert for water movement is listed on Metro's inventory of problematic culverts

Land Use

- One mile outside Urban Growth Boundary
- Zoning is agricultural on parcels surrounding site; some nearby parcels are rural residential
- Metro owns adjacent parcel to east of culvert on north side of Scholls Ferry Road

Land Use Considerations

The land on both sides of the culvert is privately owned, which means that sometime in the future it could be developed. Metro could consider buying the property or work with property owners to develop a conservation easement to preserve wildlife access to the crossing.

Underpass Concept

Because this is a critical connection between significant upland habitat on Cooper Mountain and the riparian habitat along the Tualatin River, it is important that the crossing meet the needs of a wide array of species. The recommended structure for this site would be a bottomless box culvert that is 8-10 ft. tall and 15-20 ft. wide, with a clear view from one end to the other. Such a structure would allow the stream to flow freely and would permit almost any animal to pass through it. Stumps, rocks, and hollow logs would provide cover for smaller animals. Although the stream ravine may already be used by wildlife as a movement corridor, fencing should be installed to guide wildlife to the crossing.

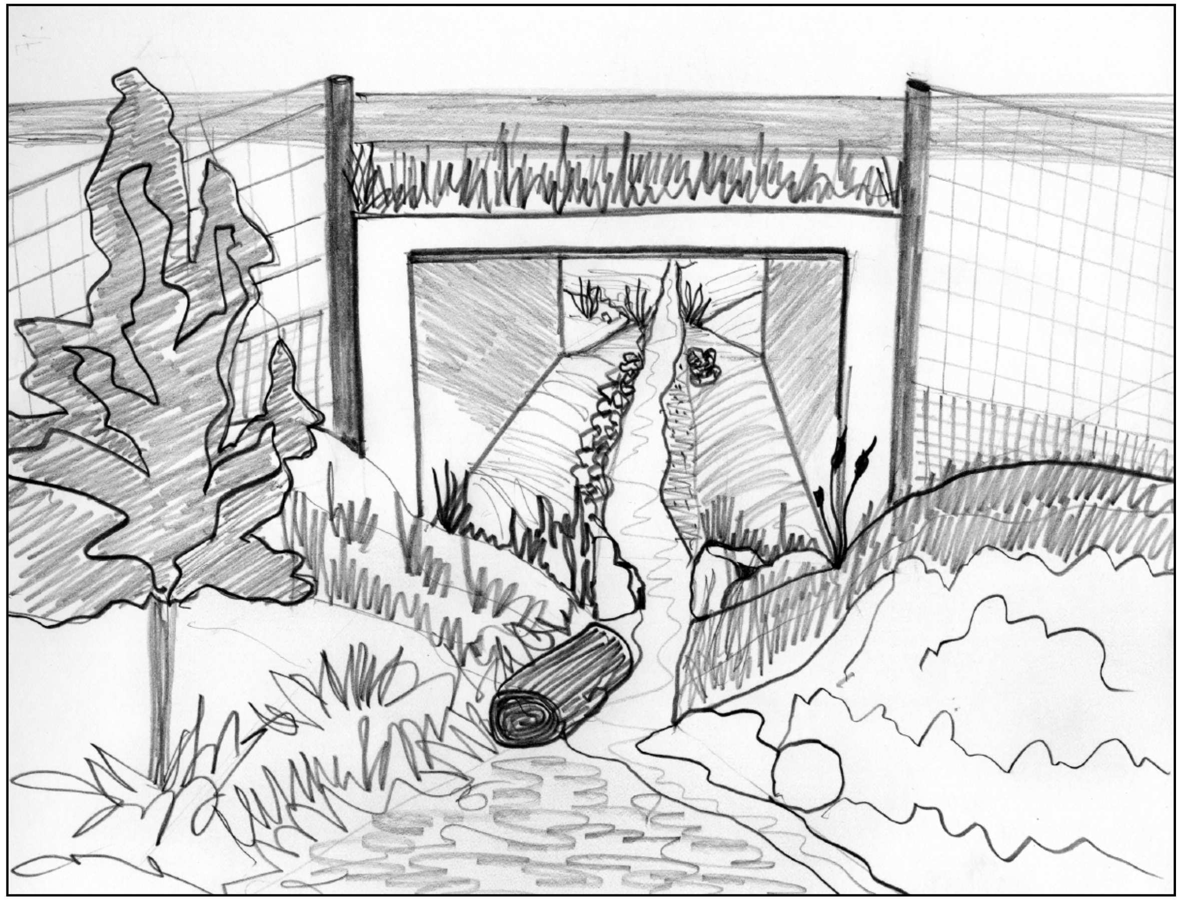
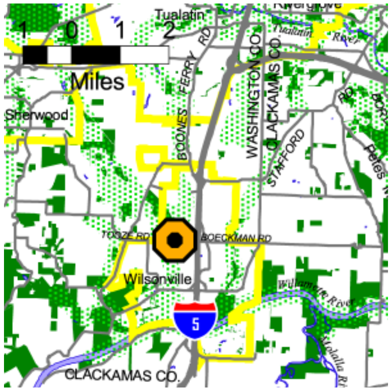


Figure 6-11. Sketch of possible underpass to accommodate wildlife and restore natural stream flow

Rough Cost Estimate[4]

- Construction cost = $300,000.
- Cost estimate includes excavation, construction of box culvert, backfill of materials, and reconstruction of roadway.

Boeckman Road



Boeckman Road Extension

The proposed alignment extension cuts through the Coffee Creek wetlands complex. The Coffee Creek wetlands complex is identified as an important wildlife habitat and corridor in the Metro Greenspaces Acquisition Report. The MTIP recognizes the project's integration of road enhancements to protect natural resources. An elevated roadway across the wetland complex would provide an opportunity for wildlife movement underneath the structure. A less expensive alternative, such as box culverts, may also be effective.

Figure 6-12. Boeckman Road alignment area, looking north

Figure 6-13. Boeckman Road alignment area, looking west

Location

- Wilsonville, OR
- Bisects Coffee Creek wetland complex

Topography

- Wetland, flat terrain
- Lowland on either side of proposed future extension

Land Use

- Inside Urban Growth Boundary
- Zoning is single-family residential southwest of proposed extension, rural to north and south
- Metro owns adjacent parcels in Coffee Creek wetland complex north of alignment

Future Growth

This opportunity site is surrounded by the Coffee Creek wetlands complex, located within the City of Wilsonville in Clackamas County. Plans for the area call for residential development while protecting surrounding agricultural land and open space. This opportunity site provides valuable habitat and an important movement corridor for many wildlife species.

Perforating the Embanked Roadway

Because the wetland complex is a valuable natural resource, a bridge spanning the whole length of the wetlands would be ideal for movement of wildlife as well as water. However, a 1000-foot viaduct structure would cost approximately $5 million,[5] which means this option is probably not financially feasible.

The preferred alternative for the City of Wilsonville is a roadway atop earthen fill.[6] One design concept is to punch multiple underpasses of various sizes through the fill to allow some movement of water and animals, but at a much lower cost than the viaduct.

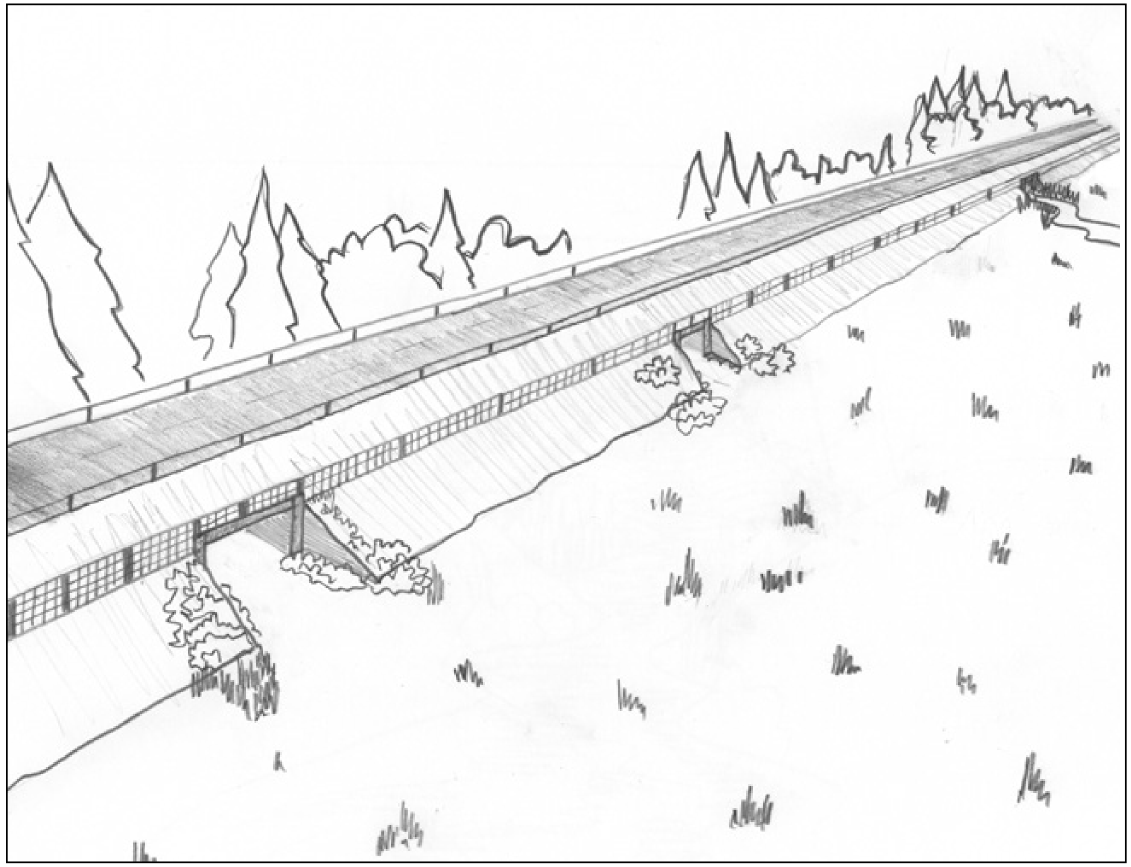


Figure 6-14. Sketch of undercrossings of various sizes perforating the raised roadway

Rough Cost Estimate[7]

- Total construction cost for a 2000-foot elevated, embanked roadway = $15.7 million.
- Incremental cost of adding three 10 ft. x 10 ft. box culverts = $540,000.
- Cost savings realized from integrating construction of the three culverts into the roadway construction = $60,000.

Pleasant Valley

Mitchell Creek Culvert

Mitchell Creek flows into Kelley Creek, providing habitat and a movement corridor for many species of mammals and fish, including elk, deer, rabbits, steelhead and cutthroat trout, and even mountain lions.[8]

The culvert for Mitchell Creek at 162nd Street south of Clatsop Road in Pleasant Valley blocks fish and wildlife passage and is listed as "highest priority" for fish passage improvements in Metro's culvert inventory. A culvert retrofit could include accommodations for animal movement through this critical linkage area.

Figure 6-15. Mitchell Creek culvert as seen from west side of 162nd Street

Figure 6-16. Mitchell Creek culvert as seen from east side of 162nd Street

Location

- Clackamas County, OR
- Mitchell Creek culvert on boundary between City of Portland and unincorporated Clackamas County
- Western edge of Pleasant Valley Concept Plan study area

Topography

- Moderate to sleep slope (roughly 30 degrees) on west side of 162nd Street
- Steep slope (roughly 50 degrees) on east side of 162nd Street
- Topography to north and south of culvert is moderate

Land Use

- Inside Urban Growth Boundary
- Zoning is single-family residential to west of culvert, rural to east of culvert
- Metro recently purchased land directly south of Mitchell Creek for its Greenspaces program

Culvert Retrofit Design

Retrofitting the existing culvert at Mitchell Creek and 162nd Street for fish passage is a high priority for Metro. Improvements could go beyond those typically made for fish and include accommodations for wildlife. The culvert could be widened, using a bottomless culvert that exceeds the width of the natural streambed to provide dry land for wildlife. The sketch on this page provides an example.

Balancing Growth and Habitat Protection in Pleasant Valley

Construction of a wildlife crossing at this opportunity site is in keeping with the Pleasant Valley Concept Plan. The concept plan addresses how to accommodate growth in the region over the next 20 years, while maintaining the integrity of the local environmental features. Construction of a wildlife crossing at Mitchell Creek and 162nd would allow for vehicle mobility as well as facilitate movement of fish and mammals and improve habitat quality in the area. The facility would exemplify the integration of development and natural resource protection emphasized in the plan.

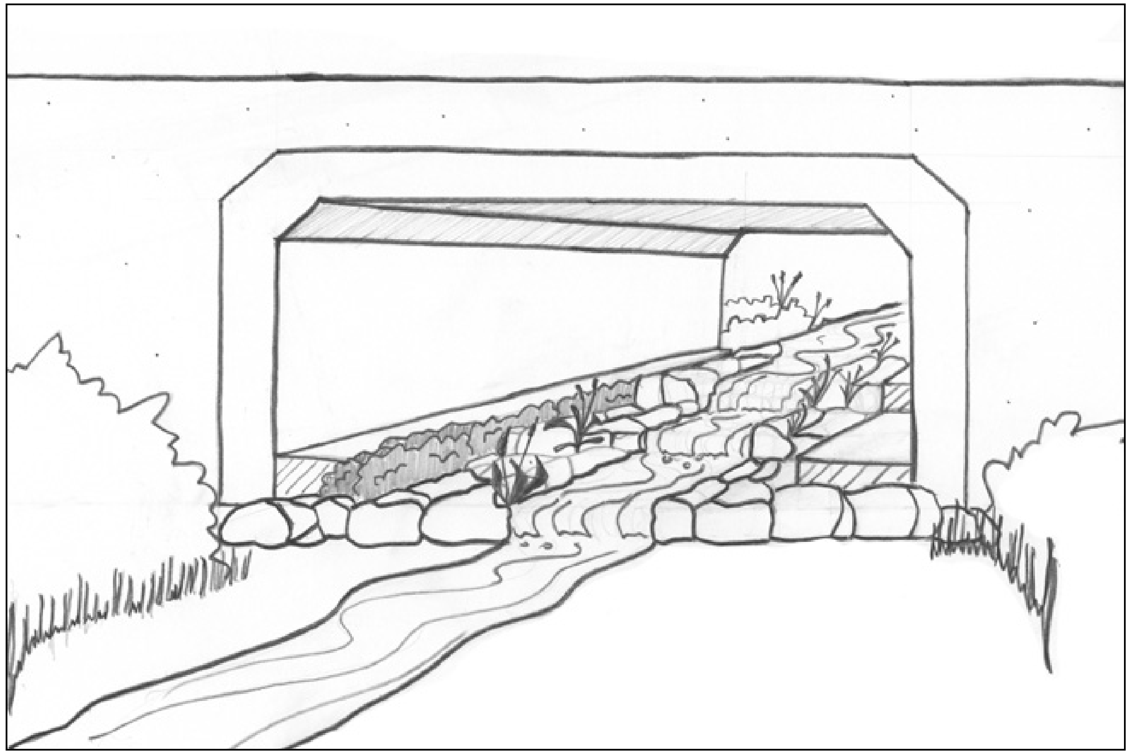


Figure 6-17. Sketch of combined fish passage and wildlife crossing

Rough Cost Estimate[9]

- Total construction cost = $400,000 to $1,000,000 depending on extent and nature of stream reconstruction.
- Cost estimate includes 80 ft. long culvert, stream reconstruction and fish ladder ($200,000 to $400,000), and wetland mitigation.

Additional Considerations

Litter such as beer cans and snack food containers found during a visit to the site suggest that it may be necessary to take measures to discourage vandalism. Ensuring there are no comfortable places to sit by encouraging moss to grow on the culvert walls and keeping the floor muddy and vegetated may be one measure. Additional measures such as fencing or a monitoring camera may also be useful.

"You have a basis here for civilization on its highest scale, and I am going to ask you a question which you may not like. Are you good enough to have this country in your possession? Have you got enough intelligence, imagination, and cooperation among you to make the best use of these opportunities?"

Lewis Mumford, in a 1938 speech
before the Portland City Club

7.0 Next Steps

The work conducted to develop this guidebook leaves the project team hopeful about the opportunities to build effective wildlife crossings in the Portland metropolitan region. However, there are several improvements that could be made to assist Metro in these efforts. These include modifying wildlife mortality data collection; encouraging the inclusion of wildlife crossings in MTIP-eligible road projects; and coordinating with other agencies on cost-sharing opportunities. These recommendations are described in the next few pages.

First things first: better data

One of the most crucial pieces of information needed to properly site a wildlife crossing is to know that one is needed. Typically, this information is dependent on the availability of wildlife mortality data. Recent efforts by Metro have made progress in this area (see Chapter 2), but small improvements in data collection could make a large difference. Some of these recommended improvements include:

More specific location of carcass pick-up—Animal control agencies have different methods for collecting and recording the location of wildlife mortality. More precise, standardized information would dramatically improve the accuracy of this information. Improved locational accuracy could include mileposting, distance from intersections or landmarks, and installing Global Positioning Systems (GPS) units in animal control vehicles.

Type of wildlife—Agencies responsible for carcass cleanup do not typically specify the type of animal picked up on the road, and could include domestic animals such as cows, horses, and dogs. Specifying more clearly the type of wildlife (e.g., deer, coyote) would help inform decisions by planners and biologists about specific design type and size of the wildlife crossing.

More funding for clean-up efforts—Due in part to budget constraints, most animal control agencies are unable to respond to pickup requests if the wildlife is smaller than a deer or elk. Furthermore, they often are unable to respond to calls about injured or frightened wildlife. Additional funding for these programs would not only assist their efforts, but would assist the efforts of local and regional agencies planning a wildlife crossing.

Although greater levels of data collection are needed to identify possible locations for wildlife crossings, the decision of where to site a crossing cannot be made purely by looking at map layers. No crossing should be sited without a visit to the area by a biologist, planner, and engineer, who should review the site for appropriate topography, vegetation, habitat quality, land use, and road geometry. See Appendix C for a sample site assessment guide.

Figure 7-1. No crossing should be sited without a visit to the area by a biologist, planner, and engineer.

Make it part of the project

Most project managers will acknowledge a tension that exists between wanting to add project amenities that enhance the aesthetic beauty of a project, and needing to cut them due to budget constraints. Amenities are considered just that—something nice to have, but not crucial to the success of the project. Although it is easy to consider a wildlife crossing as a project amenity, doing so is a mistake. The I-84 project in Idaho described in Chapter 3 illustrates the importance of including a crossing during initial road construction.

Crossings for wildlife need to be considered an integral part of a road project, one that will add value in the short and long term. Making this shift in thinking without a federal mandate (similar to ESA) is difficult. However, Metro can help by adding a provision for wildlife crossings to its MTIP evaluation criteria. All agencies competing for MTIP funds will then respond to this criterion, and those that include mitigation for wildlife impacts could receive funding priority.

Explore cost-sharing opportunities

Building wildlife crossings as part of an initial construction project is, overall, far less expensive than retrofitting an existing roadway—it avoids the disruption of excavating, traffic management, and disruption to pavement, shoulders, utilities, and the natural landscape. However, when retrofits are unavoidable, combining wildlife crossings projects with other types of retrofit projects is a good way to defray some of the costs. Cost-sharing opportunities described in Chapter 4 include the following:

Culvert retrofits—Metro's culvert program identifies culverts that block fish passage in the region. Retrofitting some of the most problematic culverts will be necessary to comply with ESA regulations. Wildlife crossings could be added on to a culvert retrofit project by widening a culvert incrementally to include dry land or a shelf for wildlife on one side.

Figure 7-2. Wildlife crossings could be added on to a culvert retrofit project by widening a culvert incrementally to include dry land or a shelf for wildlife.

Bridge repairs—The state has identified numerous bridges that are at the end of their lifespan and in need of repair or replacement. A viaduct can be created by extending the bridge footprint to include dry land on one or both sides of the bridge to accommodate wildlife. Metro is encouraged to partner with the state to create bridges that will work for people and wildlife.

Multipurpose paths—Federal funding is available through the Recreational Trails Program that could be used for paths that benefit wildlife and human activity. Urban locations, such as nature trails in public parks, could be an effective location for these crossings.

Maintain land use goals

Ultimately, containing the footprint of human development will have the greatest impact on maintaining wildlife habitat. Wildlife crossings, therefore, fit within the broader land use planning goals of the State of Oregon and Metro. Cluster development with buffers or transition zones between centers and natural areas preserves more area for wildlife to move. Metro is encouraged to continue coordination with the cities in its jurisdiction to include buffers or transitional zones in their comprehensive plans, and to help cities map habitat corridors and plan connected greenspaces. The recently published Pleasant Valley Concept Plan provides a good model for this type of land use planning.

Resource

Pleasant Valley Concept Plan
City of Gresham, Community and Economic Development Department
http://www.ci.gresham.or.us/departments/cedd/cp/pleasantvalley/pv_plan.htm

Figure 7-3. This illustrative plan of the Nursery neighborhood in Pleasant Valley shows clustered development, open space, and environmental transitional zones.

Demonstration project

Once an agency has identified the need, possible design solutions, costs, and funding for a wildlife crossing, the best way to test how it will work is to build one. Future planning efforts in the Damascus area present an opportunity for a wildlife crossing demonstration project. Damascus can benefit from Clackamas County's good road mortality data collection process—Metro received better data on wildlife-vehicle conflicts from this county then elsewhere in the region. Damascus was very recently brought inside the Urban Growth Boundary and long-range planning efforts are underway. This provides Metro with an opportunity to identify possible hot spots, integrate a crossing into the comprehensive plan and MTIP, and build a crossing as part of a road construction or other development project.

Monitoring

As discussed in Chapter 3, monitoring is a crucial element of a wildlife crossing plan, but one that is often forgotten. Metro could require that monitoring be included as part of any crossing project. Collaboration with academic researchers and graduate students, as well as volunteers, could help minimize monitoring costs.

This page left blank intentionally.

Appendix A

Identifying "Hot Spots"

The siting of a wildlife crossing facility requires an identification of wildlife movement patterns and an assessment of the impacts roads impose on wildlife. It is important to understand where the problem areas exist, so that the wildlife crossing is sited in the most effective location. The techniques used in previous wildlife projects have varied from the basic to the highly sophisticated. They include the collection and visual display of deer/elk roadkill data, field research that involves camera surveys and snow tracking, and GIS analysis, including least-cost path analysis to model wildlife movement corridors. Examples come from Maine, Montana, Washington State, and the country of Slovenia.

According to Craighead et al.[1] in their article about identifying wildlife movement in the Bozeman Pass area of Montana, there are two steps to conducting an analysis of potential roadway impacts on wildlife. First, researchers should collect and map wildlife-vehicle conflict data. Second, the analysis requires researchers to identify the routes that animals use to cross the existing or proposed highway.

A State of Maine study focused on the roadkill portion of the analysis.[2] The state transportation department utilized fairly simple data collection and mapping techniques to identify an appropriate location for a wildlife crossing. The researchers identified and mapped statewide "high crash locations," defined as locations exhibiting a high number of wildlife-related crashes per vehicle mile traveled. They then visited those locations and identified site-specific features that contributed to road-related wildlife mortality. This two-step process helped them understand why the sites were "hot spots."

In the Montana study, analysts used GIS to develop models that predicted movement corridors of animals.[3] Researchers in Washington State used similar GIS techniques to identify wildlife movement corridors near a proposed road project near Snoqualmie Pass.[4] They began with data collection, including mapping wildlife mortality data and using camera surveys and snow tracking studies to find locations where animals crossed the roadway. Then they created GIS landscape models using the wildlife-vehicle conflict and other data, such as vegetation and waterways. The models allowed the researchers to identify animal movement corridors.

Slovenia planners used an equally sophisticated GIS analysis to determine animal movement corridors.[5] GIS and artificial intelligence-based modeling were used to classify habitat suitability. The knowledge base for the system, induced from recorded animal sightings, was linked to GIS thematic layers. The main factors considered by the system were: land use types, other human impacts, and topography. This process identified wildlife movement corridors and suitable locations for the construction of wildlife crossings.

These examples are meant to illustrate the range of options available for analysis, not to set out a procedure that will work in every case. It is also important to note that these techniques were used in rural areas, where larger animals such as deer, elk, and bear were present. Some of these techniques, including mapping of vehicle-related wildlife mortality data, may not be an effective way of measuring roadway impacts where large mammals are not present. These steps are intended to guide a study of habitat and animal movement that is appropriate for a particular location.

This page left blank intentionally.

Appendix B

Selected Species of the Metro Region

The following is a selected list of known mammals, amphibians, and reptiles in the Metro region. Fish and bird species are not included in this list. The list is adapted from the *Metro Region Species List*.[1]

Common Name	Category	Genus/Species	Migratory Status
Virginia Opossum*	Mammal	*Didelphis virginiana*	R*
Vagrant Shrew	Mammal	*Sorex vagrans*	R
Pacific Water Shrew	Mammal	*Sorex bendirii*	R
Water Shrew	Mammal	*Sorex palustris*	R
Trowbridge's Shrew	Mammal	*Sorex trowbridgii*	R
Shrew-mole	Mammal	*Neurotrichus gibbsii*	R
Townsend's Mole	Mammal	*Scapanus townsendii*	R
Coast Mole	Mammal	*Scapanus orarius*	R
Yuma Myotis	Mammal	*Myotis yumanensis*	R / S
Little Brown Myotis	Mammal	*Myotis lucifugus*	R / S
Long-legged Myotis	Mammal	*Myotis volans*	R / S
Fringed Myotis	Mammal	*Myotis thysanodes*	R / S
Long-eared Myotis	Mammal	*Myotis evotis*	R / S
Silver-haired Bat	Mammal	*Lasionycteris noctivagans*	R / S
Big Brown Bat	Mammal	*Eptesicus fuscus*	R / S
Hoary Bat	Mammal	*Lasiuris cinereus*	R / S
Pacific Western Big-eared Bat	Mammal	*Corynorhinus townsendii townsendii*	R / S
Brush Rabbit	Mammal	*Sylvilagus bachmani*	R
Eastern Cottontail*	Mammal	*Sylvilagus floridanus*	R*
Mountain Beaver	Mammal	*Aplodontia rufa*	R
Townsend's Chipmunk	Mammal	*Tamias townsendii*	R
California Ground Squirrel	Mammal	*Spermophilus beecheyi*	R
Eastern Fox Squirrel*	Mammal	*Sciurus niger*	R*
Eastern Gray Squirrel*	Mammal	*Sciurus carolinensis*	R*
Western Gray Squirrel	Mammal	*Sciurus griseus*	R
Douglas' Squirrel	Mammal	*Tamiasciurus douglasii*	R
Northern Flying Squirrel	Mammal	*Glaucomys sabrinus*	R
(Western pocket gopher)	Mammal	*(Thomomys mazama)*	(R)

Common Name	Category	Genus/Species	Migratory Status
Camas Pocket Gopher	Mammal	*Thomomys bulbivorus*	R
American Beaver	Mammal	*Castor canadensis*	R
Deer Mouse	Mammal	*Peromyscus maniculatus*	R
Bushy-tailed Woodrat	Mammal	*Neotoma cinerea*	R
Western Red-backed Vole	Mammal	*Clethrionomys californicus*	R
Heather Vole	Mammal	*Phenacomys intermedius*	R
White-footed Vole	Mammal	*Arborimus albipes*	R
Red Tree Vole	Mammal	*Arborimus longicaudus*	R
Gray-tailed Vole	Mammal	*Microtus canicaudus*	R
Townsend's Vole	Mammal	*Microtus townsendii*	R
Long-tailed Vole	Mammal	*Microtus longicaudus*	R
Creeping Vole	Mammal	*Microtus oregoni*	R
Water Vole	Mammal	*Microtus richardsoni*	R
Common Muskrat	Mammal	*Ondatra zibethicus*	R
Black Rat*	Mammal	*Rattus rattus*	R*
Norway Rat*	Mammal	*Rattus norvegicus*	R*
House Mouse*	Mammal	*Mus musculus*	R*
Pacific Jumping Mouse	Mammal	*Zapus trinotatus*	R
Common Porcupine	Mammal	*Erethizon dorsatum*	R
Nutria*	Mammal	*Myocastor coypus*	R*
Coyote	Mammal	*Canis latrans*	R
Red Fox	Mammal	*Vulpes vulpes*	R
Gray Fox	Mammal	*Urocyon cinereoargenteus*	R
(Gray Wolf - extirpated)	Mammal	*(Canis lupus)*	(S)
Black Bear	Mammal	*Ursus americanus*	S
(Grizzly Bear)	Mammal	*(Ursus arctos)*	(R)
Common Raccoon	Mammal	*Procyon lotor*	R
Ermine	Mammal	*Mustela erminea*	R
Long-tailed Weasel	Mammal	*Mustela frenata*	R
Mink	Mammal	*Mustela vison*	R
Striped Skunk	Mammal	*Mephitis mephitis*	R
Western Spotted Skunk	Mammal	*Spilogale gracilis*	R
Northern River Otter	Mammal	*Lontra canadensis*	R
Mountain Lion (Cougar)	Mammal	*Puma concolor*	S
Bobcat	Mammal	*Lynx rufus*	S
Domestic Cat (feral)*	Mammal	*Felis domesticus*	R*

Common Name	Category	Genus/Species	Migratory Status
California Sea Lion	Mammal	*Zalophus californianus*	S
Roosevelt Elk	Mammal	*Cervus elaphus roosevelti*	S
(Columbian White-tailed Deer)	Mammal	*(Odocoileus virginiana leucurus)*	(R)
Mule Deer	Mammal	*Odocoileus hemionus*	R
Northwestern Salamander	Amphibian	*Ambystoma gracile*	R
Long-toed Salamander	Amphibian	*Ambystoma macrodactylum*	R
Pacific Giant Salamander	Amphibian	*Dicamptodon tenebrosus*	R
Cope's Giant Salamander	Amphibian	*Dicamptodon copei*	R
Columbia Torrent Salamander	Amphibian	*Rhyacotriton kezeri*	R
Cascade Torrent Salamander	Amphibian	*Rhyacotriton cascadae*	R
Rough-skinned Newt	Amphibian	*Taricha granulosa*	R
Dunn's Salamander	Amphibian	*Plethodon dunni*	R
Western Red-backed Salamander	Amphibian	*Plethodon vehiculum*	R
Ensatina	Amphibian	*Ensatina eschscholtzii*	R
Clouded Salamander	Amphibian	*Aneides ferreus*	R
Oregon Slender Salamander	Amphibian	*Batrachoseps wrighti*	R
Western Toad	Amphibian	*Bufo boreas*	R
Tailed Frog	Amphibian	*Ascaphus truei*	R
Pacific Chorus Frog (tree frog)	Amphibian	*Hyla regilla*	R
Northern Red-legged Frog	Amphibian	*Rana aurora aurora*	R
(Oregon Spotted Frog - extirpated)	Amphibian	*(Rana pretiosa)*	(R)
Bullfrog*	Amphibian	*Rana catesbeiana*	R*
Common Snapping Turtle*	Reptile	*Chelydra serpentina*	R*
Painted Turtle	Reptile	*Chrysemys picta*	R
Northwestern Pond Turtle	Reptile	*Clemmys marmorata marmorata*	R
Red-eared Slider*	Reptile	*Trachemys scripta elegans*	R*
Northern Alligator Lizard	Reptile	*Elgaria coerulea*	R
Southern Alligator Lizard	Reptile	*Elgaria multicarinata*	R
Western Fence Lizard	Reptile	*Sceloporus occidentalis*	R
Western Skink	Reptile	*Eumeces skiltonianus*	R
Rubber Boa	Reptile	*Charina bottae*	R
Racer	Reptile	Coluber constrictor	R
Sharptail Snake	Reptile	*Contia tenuis*	R
Ringneck Snake	Reptile	*Diadophis punctatus*	R
Gopher Snake	Reptile	*Pituophis catenifer*	R
Western Terrestrial Garter Snake	Reptile	*Thamnophis elegans*	R

Common Name	Category	Genus/Species	Migratory Status
Northwestern Garter Snake	Reptile	*Thamnophis ordinoides*	R
Common Garter Snake	Reptile	*Thamnophis sirtalis*	R

* Indicates species that are non-native (also known as alien or introduced) to Metro region.

( ) Parentheses indicate a species that was historically present but was extirpated (locally extinct) from the Metro region within approximately the last century.

Migratory Status

R = Permanent resident (lives in the area year-round)
S = Short-distance migrant (from elevational to regional migration, e.g., across several states)

For questions about this list, contact Metro Natural Resource Planning at (503) 797-1839.

Appendix C

Site Assessment

The following pages are designed to guide a planner through the process of assessing the site of a potential wildlife crossing. It is not comprehensive, and it is not meant to substitute for thorough analyses conducted by engineers and wildlife biologists. Instead, the worksheets guide the planner towards collecting the types of preliminary data necessary to plan a crossing and/or prepare for collaboration with engineers, biologists, and other consultants. The purpose of completing the checklists is to gather enough information to be able to determine if a crossing is feasible and—where appropriate—get to the design concept phase.

The worksheets are based on guidelines provided in this document. They were designed by the project team and tested through the process used to select and analyze the opportunity sites described in Chapter 6. Comments and suggestions were solicited from transportation planners, a wildlife biologist, a natural resource planner, a transportation engineer, and others.

Step 1: Gather Background Information

1. ***Identify site and issue:*** ____

____

____

2. ***Safety Analysis:***
   - Review applicable safety data, including information on wildlife-vehicle conflicts:
     This data is available from the ODOT Crash Analysis and Reporting Unit, (503) 986-4240 or *www.odot.state.or.us/tdb/accident_data*.
   - Gather data on traffic volumes and counts:
     This information is available from the Data Resource Center at Metro, (503) 797-1742 or *www.metro-region.org*.

3. ***Site Suitability Analysis:***

Conduct a preliminary analysis in GIS to provide contextual information on the location of the crossing. The analysis should identify the land use and zoning of adjacent properties, as well as habitat indicators such as vegetative cover, rivers and streams, and wildlife corridors as defined by Metro. The following data sources may be appropriate: wildlife corridors, Metro's Culvert Inventory, taxlots, zoning, rivers, vegetative cover, wildlife mortality, and/or aerial photos. All data are available from the Data Resource Center at Metro, (503) 797-1742 or *www.metro-region.org*. Additional data may also be available from individual jurisdictions.

Maps should be designed to answer the following questions:

- Is the crossing located within a wildlife corridor?
- Are there any wildlife mortalities recorded near the crossing site? Approximately how many per year?
- What type of habitat (wetland, riparian, upland) surrounds the crossing site?
- What are the adjacent land uses and zoning? Are there plans that propose different land uses and zoning?
- Is the site listed on Metro's Culvert Inventory? If so, how was the habitat quality rated? What priority was the culvert given?

Step 2: Field Visit

Materials: Camera, measuring tape, inclinometer, maps created during office analysis, hardhat, and orange vest.

Site location and description (Be as specific as possible. Include mileposts, landmarks, signage, etc.): ________________________

____

____

____

____

Time/Day/Month of Site Analysis: ________ Date ________ Day of Week ________Time of Day

Describe Current Weather Conditions: ____

1. Characterization of Wildlife Habitat

Describe the habitat indicators located at the site (types of trees, vegetation, etc): ________________________

____

____

____

____

Note: A more detailed habitat analysis will be necessary to complete the final planning and design of a crossing. Contract with a wildlife biologist or other qualified professional to follow the method outlined in Metro's 2001 Wildlife Habitat Assessment Methodology *and conduct assessment as provided in Metro's* Wildlife Habitat Assessment Narrative Sheet. *Both documents are available from Metro, Natural Resource Planning, (503) 797-1839 or 2040@metro-region.org.*

2. *Water Features*

Describe water features: ____

____

____

Stream Width: ______________________________

Stream Depth: ______________________________

For year-round stream flow measurements, contact U.S. Geological Survey and/or check with local jurisdiction.

3. *Land Use*

Use maps to confirm adjacent land uses.

4. *Topography*

Sketch a cross-section of the roadway indicating the slope on either side. The sketch should be specific to the site of the potential crossing. Provide multiple sketches if considering more than one crossing location or if the potential crossing site covers a large area. Indicate relative scale and note the slope angle down or up from road.

5. Road Characteristics

A. Number of Lanes: ______________________________

B. Shoulder Width: ______________________________

C. Road Width: ______________________________

D. Sidewalk Width: ______________________________

E. Pavement Material: ______________________________

F. Estimated sight distance on a vertical/horizontal curve: __________

G. Posted Speed Limit: ______________________________

Does speeding seem to be a problem near the crossing site? ________

H. Existing Wildlife Mitigation Measures:

- ☐ Animal crossing signs
- ☐ Speed Bumps
- ☐ Other (describe) ______________________________

I. Presence of Power Lines? ______________________________

Other notes on roadway: ____

____

____

____

____

6. *Existing Culvert (if a retrofit project)*

Provide sketches of the culvert openings. Include size of culvert opening (diameter), vertical distance from ground, vertical and horizontal distance from the edge of the road, distance above or below the "level" of the channel (sometimes the inlet and outlet can be partially buried or hanging up in the air due to erosion), and the type of inlet/outlet treatment (which might include a concrete retaining wall, headwall, rip-rap, gabions, or no treatment).

Upstream	Downstream

7. ***Structural Considerations***

Are there topographical or other conditions at the site that present opportunities or impose constraints on certain types of structures? Use the list below to address these factors.

	Opportunities	**Constraints**
Culvert		
Bridge/Viaduct		
Overpass		

8. ***Questions/Comments/Issues for Further Analysis***

Step 3: Moving Forward

1. ***Consultation with Biologist and Engineer***

   If the field checklist was completed without the assistance of an engineer and a wildlife biologist, consultation with those professionals will be important in determining the type and size of crossing appropriate for a given location.

2. ***"Back of the Envelope" Cost Estimate***

   A preliminary assessment of costs should include a number of factors, including:

   - Road width, length of wildlife crossing
   - Cost of easement or property acquisition, if necessary
   - Construction materials
   - Maintenance costs
   - Monitoring costs

3. ***Identification of Potential Funding Options***

   The most important factors in determining the availability funding for a wildlife crossing are the jurisdiction sponsoring the project and the goals the project claims to pursue. A state highway project may qualify for different funds than a county project, for example, and a project that will improve fish passage will qualify for different funds than one that provides bicycle and pedestrian facilities.

4. ***Regulatory Issues***

   Regulatory issues are also affected by jurisdiction, and are also dependent on the habitat and properties affected. Some questions to consider:

   - Will construction of the crossing affect a wetland?
   - Will the facility affect private property?
   - Will the crossing affect or serve endangered species?

5. Potential Roadblocks

The planner should attempt to anticipate issues that may be controversial and prepare activities that will address the controversy. Stakeholders should be identified, and outreach programs, including focus groups, workshops, and public meetings, should be considered to address stakeholder concerns.

6. Future Efforts

If the analysis has determined a need for a wildlife crossing facility, how can it be incorporated into local and regional plans? A wildlife crossing project that is included as an element of future improvements may be easier to implement than one that is added later as a facility amenity.

Acronyms

AASHTO - American Association of State Highway and Transportation Officials
CIP - Capital Improvement Plan
DEQ - Department of Environmental Quality
ESA - Endangered Species Act
EA - Environmental Assessment
EIS - Environmental Impact Study
GIS - Geographic Information Systems
GPS - Global Positioning System
HEP - Hazard Elimination Program
MPO - Metropolitan Planning Organization
MTIP - Metropolitan Transportation Improvement Program
NEPA - National Environmental Policy Act
NHTSA - National Highway Traffic Safety Administration
ODFW - Oregon Department of Fish and Wildlife
ODOT - Oregon Department of Transportation
PSU - Portland State University
RLIS - Regional Land Information System
STIP - State Transportation Improvement Program
TE - Transportation Enhancements
TEA-21 - Transportation Equity Act for the 21st Century

References

Chapter One

1. U.S. Department of Transportation, Federal Highway Administration. (2002). International Technology Exchange Program. *Wildlife Habitat Connectivity Across European Highways*. Report #FHWA-PL-02-011. Available online: http://www.itre.ncsu.edu/cte/gateway/scantour_index.html. Accessed May 2003.

2. U.S. Department of Transportation, Federal Highway Administration. (2002). Ibid.

3. Robbins, E. (2003). No More Road Kill: What it takes to make highways friendly to animals. *Planning*. February 2003, Vol. 69, No. 2, p. 33-34.

4. Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Florida Hwy 46 Black Bear Cast-in-place Bottomless Culvert*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=&locstate=FL&Submit=Search&pID=735. Accessed May 2003.

5. U.S. Department of Transportation, Federal Highway Administration. (2002). Ibid.

6. Wildlife Crossings Toolkit website. (n.d.). Project Detail Page: *Amherst Spotted Salamander Slotted Drain Culverts*. Available online: http://www.wildlifecrossings.info/beta2.htm Accessed June 2003.

7. U.S. Department of Transportation, Federal Highway Administration. (2002). Ibid.

Chapter Two

1. Forman, R.T.T and Deblinger, R.D. (1998). The Ecological Road-Effect Zone for Transportation Planning and Massachusetts Highway Example. In Evink, G.L., Garrett, P., Zeigler, D. and J. Berry (eds.) *Proceedings of the International Conference on Wildlife Ecology and Transportation.* (Florida Department of Transportation Publication FL-ER-69-98). Florida Department of Transportation: Tallahassee, Florida.

2. Metro, Regional Parks and Greenspaces Department. (2002). Attachment Two. *Metro's Technical Report for Goal 5*. Parks and Greenspaces Department Publication. Metro: Portland, OR.

3. Texas Transportation Institute. (2002). *2002 Urban Mobility Study: Portland and Vancouver, OR.* Available online: http://mobility.tamu.edu/ums/study/mobility_data/. Accessed May 2003.

4. American Forests. (2001). *Regional ecosystem analysis for the Willamette/Lower Columbia region of northwestern Oregon and southwestern Washington State*. Available online: http://www.americanforests.org/resources/rea/. Accessed May 2003.

5. Metro, Regional Parks and Greenspaces Department. (1997). *Loss of Natural Areas, 1989-1998*. Regional Parks and Greenspaces Department Publication. Metro: Portland, OR.

6. Oregon Department of Environmental Quality. (1996). *Water Quality Limited Streams 303(d) List*. Available online: http://www.deq.state.or.us/wq/303dlist/303dpage.htm. Accessed May 2003.

7. Donnelly, R.E. and J.M. Marzluff. (In review). Designing research to advance the management of birds in urbanizing areas. *Proceedings of the International Urban Wildlife Conference*. Bill Shaw et al. (eds.) University of Arizona, Phoenix, AZ.

8. Soule, M.E. (1991). Land use planning and wildlife maintenance: guidelines for conserving wildlife in an urban landscape. *Journal of the American Planning Association*. Vol. 57. No.3, Summer 1991.

9. Portland Parks and Recreation. (1995). *Forest Park Natural Resources Management Plan*. Bureau of Planning. Portland, OR.

10. Soule, M.E. (1991) Ibid.

11. Pleasant Valley Project Partners. (2002). Habitat Linkages Map. *Pleasant Valley Concept Plan.* Available online: http://www.ci.gresham.or.us/departments/cedd/cp/pleasantvalley/pv_plan.htm. Accessed June 2003.

12. Nebel, B.J. and Wright, R. T. (1995). *Environmental Science: The Way the World Works, 4th ed.* Prentice Hall: Englewood Cliffs, NJ.

13. Sallinger, B. (2003). Bob Sallinger. Director, Wildlife Care Center, Audubon Society of Portland. Personal communication. April 2003.

14. The Humane Society of the United States. (2003). *Creating Safe Passageways for Wildlife*. Available online: www.hsus.org/ace/16206. Accessed May 2003.

15. Helping Our Peninsula's Environment. (2000). *Animals Killed by Cars*. Available online: www.1hope.org/carkill.htm. Accessed May 2003.

16. Conover, M.R., W.C. Pitt, K.K. Kessler, T.J. DuBow, and W.A. Sanborn. (1995). Review of Human Injuries, Illnesses, and Economic Losses Caused by Wildlife in the United States. In Transportation Research Board, (2002). *National Cooperative Highway Research Program Synthesis #305, Interaction Between Roadways and Wildlife Ecology*. Available online: http://www4.trb.org/trb/onlinepubs.nsf/web/nchrp_synthesis. Accessed May 2003.

17. National Safety Council. (2002). *Injury Facts, 2002 Edition.* National Safety Council Publication: Itasca, IL.

18. United States Department of Transportation, National Highway Traffic Safety Administration. (2001). *Traffic Safety Facts 2001*. Available online: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/TSF2001.pdf. Accessed April 2003.

19. Decker, D.J., Loconti-Lee, K.M., and N.A. Connelly. (1990). *Incidence and Costs of Deer-Related Vehicular Accidents in Tompkins County, New York*. Human Dimensions Research Unit Publication (98-7). Department of Natural Resources, Cornell University: Ithaca, NY. Cited in Curtis, P.D. *Impacts and Economic Costs of Deer in Suburban Landscapes*. Available online: http://www.arec.umd.edu/Policycenter/Deer-Management-in-Maryland/curtis.htm. Accessed April 2003.

20. TRB Subcommittee on Animal-Vehicle Crash Mitigation. (2002). *Meeting Minutes, July 2002.* Western Transportation Institute Web page. Available online: http://www.coe.edu/wti/. Accessed June 2003.

21. Hughes, W.E., Saremi, A. R. and Paniati, J.F. (1996). Vehicle-Animal Crashes: An Increasing Safety Problem. *ITE Journal.* Vol. 66, No. 8, August 1996.

22. Vogel, S. (2003). Sylvia Vogel. Crash Analysis and Reporting Unit. Oregon Department of Transportation. Personal Communication. May 2003. Data available online: http://www.odot.state.or.us/tdb/accident_data/. Accessed May 2003.

23. Sallinger, B. (2003). Ibid.

24. Metro. (2000). 2020 Population and Employment Forecast. *2000 Regional Transportation Plan (Second Edition)*. Available online: http://www.metro-region.org/article.cfm?ArticleID=236. Accessed March 2003.

25. Fisher, C. (2003). Christy Fisher. Oregon and Idaho Insurance Information Center. Personal Communication. May 2003.

26. Clackamas County Department of Transportation and Development. (2003). *Activity Cost Summary: July 1, 2000 to June 30, 2002.*

27. Sielecki, L.E. (2000). *WARS 2000: Wildlife Accident Reporting System, 2000 Annual Report*. British Columbia Ministry of Transportation and Highways, Environmental Services Section. In *Wildlife Crossings Toolkit*. Available online: http://www.wildlifecrossings.info/sa020.htm. Accessed June 2003.

28. National Safety Council. (2002). Ibid.

29. National Safety Council. (2002). Ibid.

30. Oregon Department of Land Conservation and Development. (2003). *Oregon's 19 Statewide Planning Goals & Guidelines*. Available online: http://www.lcd.state.or.us. Accessed May 2003.

31. Metro. (1998). *Title 3 Model Ordinance.* Available online: http://www.metro-region.org/article.cfm?articleid=887. Accessed May 2003.

32. Metro. (2002). Presentation: Livable Streets and Metro Regional Culvert Inventory. Unpublished presentation.

33. Metro. (1998). Ibid.

34. Metro. (2001). *Metro's Open Spaces Land Acquisition Report to Citizens*. Available online: http://www.metro-region.org/article.cfm?articleid=469. Accessed May 2003.

35. Metro Transportation Division. (2002). *Green Streets: Innovative Solutions for Stormwater and Stream Crossings*. Transportation Division Publication. Metro: Portland, OR.

36. Metro. (1995). *2040 Growth Concept Plan*. Metro: Portland, OR.

37. Metro. (2000). *2000 Regional Transportation Plan (Second Edition)*. Available online: http://

www.metro-region.org/article.cfm?ArticleID=236. Accessed March 2003.

A. Braunstein, M. (1998). Roadkill: Driving Animals to their Graves. *Animal Issues*. Vol. 29, No. 3, Fall 1998. Available online: http://www.api4animals.org/doc.asp?ID=680. Accessed April 2003.

B. No source referenced.

C. Metro. (2002). *Metro approves major urban growth boundary expansion*. Available online: http://www.metro-region.org/article.cfm?articleid=2368. Accessed March 2003.

D. National Safety Council. (2002). *Injury Facts, 2002 Edition*. National Safety Council Publication: Itasca, IL.

Chapter Three

1. U.S. Department of Transportation, Federal Highway Administration. (2002). Ibid.

2. United States Department of Transportation, Federal Highway Administration. (2000). Bear Underpasses. *Critter Crossings: Linking Habitat and Reducing Roadkill website*. Available online: http://www.fhwa.dot.gov/environment/wildlifecrossings/bear.htm Accessed May 2003.

3. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

4. Transportation Research Board. (2002). *National Cooperative Highway Research Program Synthesis #305, Interaction Between Roadways and Wildlife Ecology*. Available online: http://www4.trb.org/trb/onlinepubs.nsf/web/nchrp_synthesis. Accessed May 2003.

5. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

6. Clevenger, A. and N. Waltho. (2000). Factors Influencing the Effectiveness of Wildlife Underpasses in Banff National Park, Alberta, Canada. *Conservation Biology,* Vol. 14, No. 1. February 2000.

7. Transportation Research Board. (2002). Ibid.

8. Ruediger, Bill. (2002). High Wide and Handsome: Designing more effective wildlife and fish crossings for roads and highways, *Proceedings of the International Conference on Ecology and Transportation,* Keystone, CO, September 24-28, 2001. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University. March 2002.

9. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

10. Wildlife Crossings Toolkit website. (2003). *Using Wildlife Behavioral Traits to Design Effective Crossing Structure*. Available online: http://www.wildlifecrossings.info/sa015.htm. Accessed May 2003.

11. Jackson, Scott D. (1999). Overview of Transportation Related Wildlife Problems. In: Evink, G. L., P. Garrett and David Zeigler, eds. *Proceedings of the Third International Conference on Wildlife Ecology*

and Transportation. FL-ER-73-99. Florida Dept. of Transportation, Tallahassee, FL.

12. Ruediger, (2001). Ibid.

13. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

14. Ruediger, (2001). Ibid.

15. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

16. Transportation Research Board. (2002). Ibid.

17. Wildlife Crossings Toolkit website. (2003). Ibid.

18. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

19. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

20. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

21. Clevenger and Waltho, (2000). Ibid.

22. Sallinger, B. (2003). Bob Sallinger. Director, Audubon Society of Portland Wildlife Care Center. Personal communication. April 2003.

23. Oregon Department of Fish and Wildlife. (1997). *Portland's Peregrine Falcons*. Available online: http://www.dfw.state.or.us/ODFWhtml/Wildlife/Peregrine/Peregrine.html. Accessed May 2003.

24. Florida Department of Environmental Protection. (2003). *Cross Florida Land Bridge*. Available online: http://www.dep.state.fl.us/gwt/cfg/landbridge.htm Accessed May 2003.

25. Skillings & Connolly. (2000). *US 93 Fish and Wildlife Crossings: 28. Mission Creek Crossing, St. Ignatius Segment*. Available online: http://www.skillings.com/Web-Page/028WC.pdf Accessed May 2003.

26. Scherer, G. (2001). The Ecology of Trail Lands, Part 6. Global Climate Change: The Gathering Storm. *American Hiker*. June 2001. Available online: http://www.americanhiking.org/news/pdfs/trail/TE_0601.pdf. Accessed May 2003.

27. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

28. United States Department of Transportation, Federal Highway Administration (2002). Ibid.

29. Wildlife Crossings Toolkit. (2002). Project Detail Page. *Banff National Park Part 3: Overcrossings*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=&locstate=&siteoverview=&Submit=Search&pID=859. Accessed May 2003.

30. Wildlife Crossings Toolkit. (2002). Ibid.

31. Maine Interagency Work Group on Wildlife/Motor Vehicle Collisions. (2001). *Collisions Between Large Wildlife Species and Motor Vehicles in Maine*. Maine Department of Transportation Publication. Available online: http://www.state.me.us/mdot/moosereport.pdf Accessed May 2003.

32. Wildlife Crossings Toolkit. (2002). Project Detail Page. *Sublett/Black Pine Mule Deer Herds and I-84 Fencing and Underpass Lessons*. Available online: http://cnr.usu.edu/crossings/simppubsearchresults.cfm?projname=black+pine+mule+deer&locstate=ID&Submit=Search Accessed May 2003.

33. Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Bitterroot Valley Small Animal Culvert Shelves*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=&locstate=mt&Submit= Search&pID=757. Accessed May 2003.

34. Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Douglas County Proposed Open-Span Bridge and Bottomless Culvert.* Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=douglas+county&locstate=co&Submit=Search&pID=834. Accessed May 2003.

35. Transportation Research Board. (2002). Ibid.

36. Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Florida Hwy 46 Black Bear Cast-in-place Bottomless Culvert*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=&locstate=FL&Submit=Search&pID=735. Accessed May 2003.

37. North Carolina State University, Center for Transportation and the Environment. (2002). *Field Trip: Healy Open Span Bridge Underpass*. Available online: http://itre.ncsu.edu/cte/gateway/banff_fieldtrip.html#site2. Accessed June 2003.

38. Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Cross-Florida Greenway I-75 Equestrian and Wildlife Overcrossing*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=&locstate=fl&Submit=Search&pID=748. Accessed May 2003.

39. See:

Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Banff National Park Part 3: Overcrossings*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=banff&locstate=&Submit=Search&pID=859. Accessed May 2003.

North Carolina State University, Center for Transportation and the Environment. (2002). *Field Trip: Healy Open Span Bridge Underpass*. Available online: http://itre.ncsu.edu/cte/gateway/banff_fieldtrip.html#site2. Accessed June 2003.

40. Wildlife Crossings Toolkit website. (2002). *Project Detail Page: Wekiva River Multiple Span Bridge*. Available online: http://cnr.usu.edu/crossings/pubdetail.cfm?projname=wekiva&locstate=fl&Submit=Search&pID=750. Accessed May 2003.

41. Wildlife Crossings Toolkit website. (2002). Ibid.

Chapter Four

1. United States Department of Transportation. Federal Highway Administration. (2001). *Transportation Enhancements Overview Page: Samples of the 12 Transportation Enhancement Activities*. Available online: http://www.fhwa.dot.gov/environment/tequalif.htm. Accessed June 2003.

2. Transportation Research Board. (2002). Ibid.

3. See:

   Federal Highway Administration. (1998). Fact Sheet: Recreation Trails Program. *TEA-21: Transportation Equity Act for the 21st Century*. Available online: http://www.fhwa.dot.gov/tea21/factsheets/rec-trl.htm. Accessed May 2003.

   Center for Wildlife Law, University of New Mexico School of Law. (n.d.) Symms National Recreational Trails Act of 1991. *Federal Wildlife and Related Laws Handbook*. Available online: http://ipl.unm.edu/cwl/fedbook/symmstra.html. Accessed May 2003.

4. Oregon Department of Transportation (2002). *Hazard Elimination Program (HEP), A guide to developing federally funded roadway safety projects*. Available online: http://www.odot.state.or.us/traffic/PDF/General/ HEP%20Program%20Guide%202002.pdf. Accessed May 2003.

5. Oregon Department of Transportation. (n.d.). Oregon's Bridge System. *Bridge System Overview*. Available online: http://www.odot.state.or.us/tsbbridgepub/BrOverview.htm. Accessed May 2003.

6. Oregon Department of Transportation, Environmental Services. (1999). *Culvert Inventory and Retrofit Program*. Available online: http://www.odot.state.or.us/eshtm/culvert.htm. Accessed May 2003.

7. See:

   Oregon Department of Transportation. (n.d.). *State and Federal Laws Relating to Bicycle and Pedestrian Facilities*. Available online: http://www.odot.state.or.us/techserv/bikewalk/plantext/laws.htm. Accessed May 2003.

   Oregon Department of Transportation. (n.d.). ODOT Interpretation of ORS 366.514. *Oregon's Bicycle and Pedestrian Program*. Available online: http://www.odot.state.or.us/techserv/bikewalk/plan_app/366514.htm. Accessed May 2003.

A. Metro, Transportation Division. (2002). Ibid.

Chapter Six

1. Details on the Hillsboro wildlife crossing were provided via a personal communications with Charlie Shell, City Engineer, City of Hillsboro and Jim Grimes, Biologist, Oregon Department of Fish and Wildlife. May 2003.

2. Details on the Cornell Road speed bumps were provided via a personal communication with Bob Sallinger, Director, Wildlife Care Center, Audubon Society of Portland. April 2003.

3. Details on the Time Oil Road wildlife crossing were provided via a personal communication with Denise Rennis, Port of Portland. May 2003.

4. Cost estimates were provided by Carl Springer, Principal, DKS Associates. May 2003.

5. Springer, C. (2003). Ibid.

6. Details on the Boeckman Road project were provided via a personal communication with Pat Carroll, City of Wilsonville. May 2003.

7. Springer, C. (2003). Ibid.

8. Pleasant Valley Project Partners. (2002). Ibid.

9. Springer, C. (2003). Ibid.

Appendix A

1. Craighead, A.C., Roberts, E.A., Craighead, F. L. (2001). *Bozeman Pass Wildlife Linkage and Highway Safety Study*. For the International Conference on Ecology and Transportation, September 2001. Available online: http://www.wildlands.org/greenpapers/bzp_icoet_2001.pdf. Accessed May 2003.

2. Maine Interagency Work Group on Wildlife/Motor Vehicle Collisions. (2001). *Collisions Between Large Wildlife Species and Motor Vehicles in Maine*. Maine Department of Transportation Publication. Available online: http://www.state.me.us/mdot/moosereport.pdf Accessed May 2003.

3. Craighead, A.C. et al. (2001). Ibid.

4. Singelton, P.H., Lehmkuhl, J.F. (1999). *Assessing Wildlife Habitat Connectivity in the Interstate 90 Snoqualmie Pass Corridor, Washington*. For ICOWET III, the International Conference on Wildlife Ecology and Transportation. Available online: www.dot.state.fl.us/emo/sched/ICOWET_III.htm. Accessed May 2003.

5. Kobler, A. & Adamic, M. (2002). *Brown Bears in Slovenia: Identifying Locations for Construction of Wildlife Bridges Across Highways*. For ICOWET III, the International Conference on Wildlife Ecology and Transportation. Slovenian Forestry Institute. University of Ljubljana: Ljubljana, Slovenia. Available online: http://www11.myflorida.com/emo/sched/kobler_p.pdf Accessed May 2003.

Appendix B

1. Metro, Natural Resource Planning Division. (2002). *Metro Region Species List*. June 2002. Metro: Portland, OR.

Figure Credits

Cover: Sketches by Radcliffe Dacanay
Title page: Photo by Kerri Sullivan

Chapter 1

1-1: Humane Society of the United States, http://www.hsus.org/ace/13409
1-2: Wildlife Crossings Toolkit, http://www.wildlifecrossings.com
1-3: Wildlife Crossings Toolkit, http://www.wildlifecrossings.com
1-4: Wildlife Crossings Toolkit, http://www.wildlifecrossings.com
1-5: American Wildlands, Science-Based Conservation for the Western Rockies, http://www.wildlands.org/l_highways.html
1-6: Wildlife Habitat Connectivity across European Highways, Figure 12, http://www.international.fhwa.dot.gov/wildlife_web.htm
1-7: Data source: Developed by project team with input from clients and classmates.

Chapter 2

2-1: Chris Knight personal website, http://www.chrisknight.net/gallery.phtml
2-2: Data source: Texas Transportation Institute, 2002 Mobility Study, http://mobility.tamu.edu/ums/study/mobility_data/
2-3: Data source: Metro Goal 5 Technical Report, http://www.metro-region.org/library_docs/nat_resource/tech_report_goal5.pdf
2-4: FHWA Critter Crossings: Linking Habitat and Reducing Roadkill, http://www.fhwa.dot.gov/environment/wildlifecrossings/
2-5: Data source: Metro Regional Land Information System (RLIS) and Metro Parks and Greenspaces Department
2-6: Data source: ODOT Crash Analysis and Reporting Unit and Metro Data Resource Center.
2-7: AI Toolkit: Software solutions for the accident investigator. http://www.aitoolkit.com/damage.htm
2-8: Mitchell Creek Culvert. Photo by Theresa Carr
2-9: Data source: Metro RLIS, Metro Regional Parks and Greenspaces Department

Chapter 3

3-1: Autobahn Online, http://www.autobahn-online.de/images/1997_09.jpg
3-2: Wildlife Habitat Connectivity Across European Highways, Figure 21, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-3: Defenders of Wildlife – Habitat and Highways Campaign, http://www.defenders.org/habitat/highways/
3-4: FHWA Critter Crossings: Linking Habitat and Reducing Roadkill, http://www.fhwa.dot.gov/environment/wildlifecrossings/photo43.htm
3-5: FHWA, Connecting Habitats Across Roads and Highways: The Swiss Experience, http://www.fhwa.dot.gov/environment/greenerroadsides/sum02p5.htm
3-6: Wildlife Habitat Connectivity Across European Highways, Figure 7, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-7: Wildlife Habitat Connectivity Across European Highways, Figure 8, http://www.international.fhwa.dot.gov/wildlife_web.htm

3-8: Wildlife Habitat Connectivity Across European Highways, Figure 7, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-9: Wildlife Habitat Connectivity Across European Highways, Figure 9, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-10: Iowa Traffic Control Devices and Pavement Markings: A Manual for Cities and Counties, http://www.ctre.iastate.edu/pubs/itcd/deer.pdf
3-11: FHWA Critter Crossings: Linking Habitat and Reducing Roadkill, http://www.fhwa.dot.gov/environment/wildlifecrossings/overpass.htm
3-12: Wildlife Habitat Connectivity across European Highways, Figure 2, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-13: Data source: Wildlife Crossings Toolkit, http://www.wildlifecrossings.com
3-14: Data source: Wildlife Crossings Toolkit, http://www.wildlifecrossings.com
3-15: Sketches by Radcliffe Dacanay
3-16: Sketches by Radcliffe Dacanay
3-17: U.S. Forestry Service, Roads/Riparian/Restoration, http://www.fs.fed.us/rm/RRR/Technologies/Culverts.html
3-18: Wildlife Habitat Connectivity across European Highways, Figure 23, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-19: Sketches by Radcliffe Dacanay
3-20: Sketches by Radcliffe Dacanay
3-21: Highway Service Center – Parks Canada Agency, http://www.hsctch-twinning.ca/reup3.jpg
3-22: Turner-Fairbank Highway Research Center, Public Roads, http://www.tfhrc.gov/pubrds/02nov/01.htm
3-23: Wildlife Habitat Connectivity across European Highways, Figure 7, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-24: Sketches by Radcliffe Dacanay
3-25: Sketches by Radcliffe Dacanay
3-26: Wildlife Habitat Connectivity across European Highways, Figure 18, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-27: Autobahn Online, http://www.autobahn-online.de/images/1998_03.jpg
3-28: Sketches by Radcliffe Dacanay
3-29: Sketches by Radcliffe Dacanay
3-30: Wildlife Habitat Connectivity across European Highways, Figure 22, http://www.international.fhwa.dot.gov/wildlife_web.htm
3-31: FHWA Critter Crossings: Linking Habitat and Reducing Roadkill, http://www.fhwa.dot.gov/environment/wildlifecrossings/lmammals.htm

Chapter 4

4-1: Cape Cod Rail Trail, www.signslanguage.com/trip.html
4-2: Oregon Bridge, http://www.odot.state.or.us/tsbbridgepub/BrOverview.htm
4-3: Wildlife Crossing Structures Field Course, http://www.itre.ncsu.edu/cte/gateway/images/recreeekbrup4.jpg
4-4: Oregon Department of Fish and Wildlife, Fish Passage Program, http://www.dfw.state.or.us/ODFWhtml/InfoCntrFish/Management/FishPassage.html

Chapter 5

5-1: Data source: Developed by project team with advisement from Jennifer Budhabhatti.
5-2: Pleasant Valley Concept Plan, http://www.ci.gresham.or.us/departments/cedd/nca/pleasantvalley/index.htm
5-3: Data source: Developed by project team.
5-4: Clackamas Town Center, www.portlandmaps.com
5-5: FHWA, Connecting Habitats Across Roads and Highways: Germany: Where Roads and Wildlife Coexist, http://www.fhwa.dot.gov/environment/greenerroadsides/sum02p3.htm
5-6: FHWA Critter Crossings: Linking Habitat and Reducing Roadkill, http://www.fhwa.dot.gov/environment/wildlifecrossings/salamand.htm
5-7: Data source: Developed by project team.
5-8: FHWA Critter Crossings: Linking Habitat and Reducing Roadkill, http://www.fhwa.dot.gov/environment/wildlifecrossings/overpass.htm

Chapter 6

6-1: Data source: Metro RLIS, culvert inventory program
6-2: Photo taken by Arianne Sperry
6-3: Photo taken by Arianne Sperry
6-4: Photo taken by Kevin Drake
6-5: Photo taken by Kevin Drake
6-6: Photo taken by Charl Everson
6-7: Photo taken by Charl Everson
6-8: Photo taken by Charl Everson
6-9: Photo taken by Kevin Drake
6-10: Photo taken by Kevin Drake
6-11: Sketch by Radcliffe Dacanay
6-12: Photo taken by Radcliffe Dacanay
6-13: Photo taken by Radcliffe Dacanay
6-14: Sketch by Radcliffe Dacanay
6-15: Photo taken by Theresa Carr
6-16: Photo taken by Theresa Carr
6-17: Sketch by Radcliffe Dacanay

Chapter 7

7-1: Photo taken by Radcliffe Dacanay
7-2: Photo taken by Arianne Sperry
7-3: Pleasant Valley Concept Plan, http://www.ci.gresham.or.us/departments/cedd/nca/pleasantvalley/index.htm