A Strategy for Mitigating Highway Impacts on Wildlife

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Abstract

Animal passage systems can be designed to facilitate movement of certain wildlife species across highways. Where the conservation of a particular species or group of species is concerned, specifically designed mitigation has proven successful for a number of species. However, the effectiveness of highway mitigation systems has not been evaluated with respect to the vast majority of wildlife. It is probable that some species do not require specific design features while others will require careful attention to factors such as placement, size, substrate, noise, temperature, light and moisture. In areas where road and highway density is high, conservation of particular species may be of lesser concern than the maintenance of overall habitat connectivity. While it is impractical to design mitigation projects that account for the specific requirements of all species affected by a highway, it may be possible to develop a generalized strategy for making highways more permeable to wildlife passage for a larger number of species. This strategy will require use of a variety of techniques given that the specific requirements for particular species may be contradictory. Some of the most effective techniques for facilitating wildlife movement (i.e. overpasses) are also quite expensive. A practical strategy for mitigating highway impacts on wildlife movement may dictate that expensive elements be reserved for areas that are identified as important travel corridors or connections between areas of significant habitat, while inexpensive elements (amphibian and reptile tunnels) can be used at appropriate areas throughout the highway alignment. In developed areas, corridors and habitat connections may be readily apparent. For highway projects affecting a significant amount of undeveloped land it may be necessary to conduct landscape analyses to identify “connective zones” for special mitigation attention.

A Strategy for Mitigating Highway Impacts on Wildlife

Introduction

Road and highway construction affects wildlife through the direct loss and fragmentation of habitat, by introducing a source of additive mortality for wildlife populations, and by disrupting animal movement and dispersal (Andrews, 1990; Bennett, 1991; De Santo and Smith, 1993; Jackson, 1999; Trombulak and Frissell, 2000). In the U.S., road and highway projects that fall within the jurisdiction of federal and state wetlands protection laws are routinely evaluated for wildlife impacts. A variety of habitat evaluation methods have been developed to help assess the impact of projects on habitat for wetlands wildlife. However, road and highway impacts on wildlife mortality, animal movement and dispersal generally receives little attention. EPA's 404(b)(1) guidelines emphasize impacts on travel corridors of aquatic species, yet, we currently lack a practical strategy for mitigating the impacts of roads and highways on wildlife movements that can easily be incorporated into highway design and permitting decisions.

Mitigating Impacts on Wildlife Movement

Tunnels have been used to help facilitate the movement of wildlife across roads and highways in Europe, Australia, Canada and the U.S. Evaluations of the effectiveness of tunnels indicate the need for careful design and placement, and that effectiveness is dependent on a variety of variables, including: size, placement, noise levels, substrate, vegetative cover, moisture, temperature, light, and human disturbance. More recently, overpass structures, also called ecoducts or green bridges, have been used to facilitate passage for a wide range of species (Berris, 1997; Keller and Pfister, 1997).

In order to design effective wildlife passage structures, attention needs to be paid to features that affect their utilization.

<u>Placement</u>: Placement of passage structures can be very important for some species, even relatively mobile species. Travel distance (to reach a passage way) may be especially important for small animals. Mammals are generally capable of learning to use underpass or overpass systems and may transfer that knowledge to succeeding generations (Ford, 1980; Ward, 1982; Singer and Doherty, 1985; Land and Lotz, 1996; Paquet and Callaghan, 1996). This is unlikely to be the case with reptiles and amphibians. This learning may result in improved mitigation success over time for more mobile species, even for underpasses that are not placed at traditional crossing points. Even so, many people consider placement to be the single, most important factor affecting the success of passage structures (Podloucky, 1989; Foster and Humphrey, 1995; Rodriguez, Crema, & Delibes, 1996; Rosell, Parpal, Campeny, Jove, Pasquina, & Velasco, 1997). One important challenge for placing wildlife mitigation structures is that wildlife crossings on a community level may not be spatially clustered (Alexander and Waters, 1999). Despite extensive efforts to facilitate wildlife passage in Banff National Park, the Trans-Canada Highway is still a barrier to movement and dispersal for many species, and Alexander and Waters (1999) suggest that it may be, in part, because crossing structures are too widely spaced.

Size: It is difficult to determine critical size thresholds for passage structures because these size thresholds undoubtedly vary from species to species. For some species, openness - the size of underpasses relative to the width of the roadway - may be more important that absolute size (Reed, Woodard, & Beck, 1979; Foster and Humphrey, 1995). Tunnel layouts that allowed animals to see the opposite end of a wildlife passage were positively correlated with utilization for some species (Rosell et al., 1997). In general, bigger is better. However, some species, such as Old World badgers (Pauline Schakenbos, pers comm.) and some small mammals (Hunt, Dickens, & Whelan, 1987; Rodriguez et al., 1996; Clevenger and Waltho, 1999), may prefer small underpasses. Based on studies of ecoducts in Europe, some have recommended that wildlife overpasses be at least 50 m wide (Keller and Pfister, 1997).

Light: Some species are hesitant to enter underpasses that lack sufficient ambient light (Jackson and Tyning, 1989; Krikowski, 1989; Jackson, 1996). Conversely, there is evidence that species that are sensitive to human disturbance (e.g. mountain lions, *Felis concolor*) avoid areas that are artificially lit (Beier, 1995). Maintenance of natural lighting through the use of overpasses, large underpasses or open-top (grated) underpasses may help address these concerns.

Moisture: Maintenance of wet substrate is important for some amphibians species. Shrews are often more active (or more mobile) on rainy nights and also may prefer wet substrates for traveling. Underpasses at stream crossings will probably suffice for species that utilize riverine or riparian habitat. However, many amphibian species do not use riparian or riverine areas for migration and the presence of flowing water may deter usage by these species. Open-top (grated or slotted) underpasses do provide sufficient moisture for crossings that lack flowing water. Alternatively, innovative stormwater systems might be designed for closed-top systems that would provide enough water to maintain moist travel conditions without creating flooded or stream-like conditions. Proper drainage is important, because some wildlife species are less likely to use structures when they contain standing water (Janssen, Lenders, & Leuven, 1997; Rosell et al., 1997; Santolini, Sauli, Malcevschi, & Perco, 1997).

Temperature: Small underpasses may create temperature disparities (inside vs. outside) that deter use by some amphibians (Langton, 1989a). Larger underpasses or open-top systems that allow for more air flow may effectively address this concern.

Noise: Traffic noise can be a problem for some mammals, especially those sensitive to human disturbance. Certain underpass designs (those with expansion joints and those with uncovered medians) can be quite noisy (Foster and Humphrey, 1995; Santolini et al., 1997). Open-top designs would be inappropriate for species that are sensitive to traffic noise. Overpass systems that incorporate tree and shrub buffers along the edges, appear to be much quieter than underpass systems.

Substrate: Some small animals feel more secure utilizing a crossing system if it provides sufficient cover. For example, rows of stumps in an underpass appear to facilitate use by small mammals (Linden, 1997). Maintaining or replicating stream bed conditions within over-sized culverts may facilitate use by salamanders, frogs, small mammals and aquatic invertebrates, thereby maintaining habitat continuity in the area of stream crossings. Certain species (e.g.

mountain pygmy possums, *Burramys parvus*) with very specific substrate requirements may require special attention at wildlife crossings (Mansergh and Scotts, 1989).

Approaches: Characteristics of the approaches to underpasses or overpasses may affect their use by some species. Forested species, such as black bears (*Ursus americanus*), prefer well vegetated approaches. Other species, such as mountain goats, appear to prefer approaches that provide good visibility. At Glacier National Park, mountain goats have apparently shifted movement patterns away from a traditional crossing point rather than utilize an underpass that offers poor visibility on the approaches (Pedevillano and Wright, 1987). The presence of cover on the approaches, in the form of vegetation, rocks and logs, may enhance use by a variety of small and mid-sized mammals (Hunt et al., 1987; Rodriguez et al., 1996; Rosell et al., 1997; Santolini et al., 1997; Clevenger and Waltho, 1999). However, vegetation at the entrance of an underpass may deter some mammals that are wary of conditions that provide ambush opportunities for predators.

Fencing: Although some species may utilize underpass or overpass systems without fences, some form of fencing does appear to be necessary for most species. Fences help guide animals to passage systems and prevent wildlife from circumventing the system. Mountain lions moving along stream corridors have been observed to leave stream valleys and cross over highways rather than utilize large culverts (Beier, 1995). This has also been observed for two species of turtles in Massachusetts (J. Milam, pers comm.). Ungulates commonly seek to avoid underpasses and will generally use them only if other access across the highway is barred (Ward, 1982). In Banff National Park an elaborate system of multiple arched fences is used to deter wildlife from walking around fences (B. Leeson, pers comm.). Some species are relatively good at circumventing fences by climbing over (black bears) or digging under (coyotes, *Canis latrans*, and European badgers, *Meles meles*,) standard fencing (Ford, 1980; Gibeau and Heuer, 1996). Standard fencing is also ineffective for small animals.

Human Disturbance: In an evaluation of underpasses in Banff National Park, human influence – either as distance to townsite or human activity within an underpass – was consistently ranked high as a significant negative factor affecting passage use by ungulates and carnivores (Clevenger and Waltho, 2000).

Interactions Among Species: Use of passage systems by predators may inhibit use by prey species (Hunt et al., 1987; Clevenger and Waltho, 1999; Clevenger and Waltho, 2000; C. Doncaster as cited in Clevenger and Waltho, 2000)

If mitigation objectives are defined too narrowly, mitigation projects can create as many problems as they solve. An obvious example of this is the use of fencing along highways to reduce wildlife road mortality, often for human safety reasons. When these fences are installed without crossing structures, they can compound the fragmentation effects of highways on populations, metapopulations and habitat. In designing wildlife passages, it is important to remember that different species have different requirements. If fence and passage systems are not designed for use by a broad range of wildlife, a project that facilitates passage for one species might constitute an absolute barrier for another.

Toward a Practical Strategy

There is evidence that animal passage systems can be designed to facilitate movement of certain wildlife species across highways. Where the conservation of a particular species or group of species is concerned, specifically designed mitigation has proven successful for a number of species. However, the effectiveness of highway mitigation systems have not been evaluated with respect to the vast majority of wildlife species affected by highways. It is probable that some species, such as raccoon (*Procyon lotor*) and skunks (*Mephitis sp*.), will not require specific design features while others will require careful attention to factors such as placement, size, substrate, noise, temperature, light and moisture. Some species, such as moles or terrestrial turtles, may represent a substantial challenge even to a single-species approach to mitigation.

In areas where road and highway density is high, conservation of particular species may be of lesser concern than the maintenance of overall habitat connectivity. There is evidence that roads and highways represent substantial barriers to wildlife movement, especially for small species with limited mobility. As blocks of habitat are carved up into smaller and more isolated pieces, facilitating wildlife movement among these blocks will be critical to the maintenance of viable wildlife communities in these areas.

While it may be impractical to design each passage structure to account for the specific requirements of all species expected to use it, it may be possible to develop a generalized strategy for making highways more permeable to wildlife passage for larger numbers of species. This strategy may require a variety of techniques given that the specific requirements for particular species may be contradictory. For example, open-top culverts may provide favorable lighting, temperature and moisture conditions for amphibians but may be too noisy for some mammals. Further, there is evidence that use of passage structures by predators may inhibit use of those structures by prey species (Hunt et al., 1987; Clevenger and Waltho, 1999; Clevenger and Waltho, 2000; C. Doncaster as cited in Clevenger and Waltho, 2000). A mix of different types of crossing structures will likely provide the most effective and comprehensive approach for facilitating animal movements across highways and railways.

Following are some elements and considerations for developing a generalize strategy for wildlife passage mitigation.

<u>Wildlife Overpasses</u>: Wildlife overpasses have been constructed in Europe, the U.S., and Canada. The most effective overpasses range in width from 50 m wide on each end narrowing to 8-35 m in the center, to structures up to 200 m wide. Soil on these overpasses, ranging in depth from 0.5 to 2 m, allows for the growth of herbaceous vegetation, shrubs and small trees. Some contain small ponds fed by rain water. Wildlife overpasses appear to accommodate more species of wildlife that do underpasses. Primary advantages relative to underpasses are that they are less confining, quieter, maintain ambient conditions of rainfall, temperature and light, and can serve both as passage ways for wildlife and intermediate habitat for small animals such as reptiles, amphibians and small mammals. They are probably less effective for semi-aquatic species, such as muskrats (*Ondatra zibethica*), beavers (*Caster canadensis*) and alligators (*Alligator*

mississippiensis). By providing intermediate habitat, overpasses may provide the only feasible means for allowing various species of moles to cross highways. The major drawback is that they are expensive.

Wildlife Bridges: Wildlife bridges are large underpasses (up to 30 m wide, 4 m high) that provide relatively unconfined passage for wildlife. These structures provide plenty of light and air movement, but are may be too dry for some species of amphibians. Wildlife bridges with open medians provide a certain amount of intermediate habitat for small mammals, reptiles and amphibians. However, open median designs are much noisier than continuous bridges and may be less suitable for species that are sensitive to human disturbance. Human activity within or around underpasses may significantly reduce their effectiveness for wildlife (Clevenger and Waltho, 2000). While less expensive than overpasses, wildlife bridges are also fairy costly.

Viaducts: Viaducts are areas of elevated roadway that span valleys and gorges. They differ from bridges in that they are typically higher and cross streams and rivers as well as adjacent valley habitats. Viaducts provide relatively unrestricted passage for riverine wildlife and species that utilize riparian areas for movement. The height of viaducts allows for maintenance of vegetated habitats beneath the structure and provides a sense of openness that is required for many species.

Expanded Bridges: Where roads and highways cross rivers and streams, expanded bridges that provide upland travel corridors adjacent to the waterway can provide passage ways for many species of riverine wildlife, as well as other species that may utilize stream corridors for travel. Higher bridges with wider areas for passage underneath tend to be more successful than low bridges and culverts (Veenbaas and Brandjes, 1999).

Oversize Stream Culverts: Where culverts are used to cross streams and small rivers, oversized culverts, large enough to allow for wildlife passage, may be used. Box culverts generally provide more room for travel than large pipes. Efforts to provide natural substrate, including large flat rocks as cover for small animals, will enhance their use by some species. Construction of benches on one or both sides of the stream to allow dry passage during normal high water periods will also enhance these structures. The optimum size for these structures is not known but, generally, the larger the better. Culverts are less expensive than expanded bridges, but are also less effective (Beier, 1995).

Upland Culverts: Not all species of wildlife readily use stream or river corridors for travel routes. Therefore, a comprehensive approach to the maintenance of habitat connectivity must include structures allowing overland movement between wetlands and uplands, between uplands and uplands, and from wetlands to wetlands. Badger pipes have been used effectively in Europe to facilitate crossing by European badgers and these structures are use by a variety of small animals (Bekker and Canters, 1997). Some mammals prefer larger culverts while others prefer smaller ones (Clevenger and Waltho, 1999). Movements to and from wetlands are particularly important for amphibians and turtles. Wildlife bridges (see above) may provide upland passage for larger wildlife species but may be spaced too far apart to adequately serve small animals. Relatively small amphibian and reptile tunnels may be a cost effective means of mitigating highway impacts where roads and highways are located between wetlands and upland habitats.

Box culverts are generally preferable over pipes. For amphibians and reptiles, larger culverts will probably accommodate more species than smaller ones. Open-top culverts can be expected to provide more light and moisture, and will be more effective for facilitating amphibian movements. Although there is evidence that amphibian and reptile tunnels are effective when used with two-lane roads (Langton, 1989b; Boarman and Sazaki, 1996; Jackson, 1996; Jenkins, 1996), it is not known how effective they will be for facilitating passage beneath highways of four or more lanes.

Dry Drainage Culverts: Culverts placed to conduct water during brief periods of runoff but otherwise dry for much of the year are used by a variety of wildlife (Rodriguez et al., 1996; Yanes, Velasco, & Suarez, 1995; Rosell et al., 1997; Clevenger and Waltho, 1999). With some attention to design considerations, these structure might effectively serve a dual role in passing both water and wildlife.

Fencing: Fencing for large and medium-sized mammals is required for underpass and overpass systems to be effective. Standard fencing may not be effective for some species (black bears, coyotes), but manipulations of wildlife trails and vegetation can also be used to guide animals to passage ways (Roof and Wooding, 1996) and learning may enhance their effectiveness for these species over time. Where fencing is used for large mammals, consideration should be given to the use of one-way gates to prevent animals that get onto roadways from being trapped between fences on both sides of the road. Fencing for small mammals, reptiles and amphibians must be specifically designed to prevent animals climbing over and through, or tunneling under the fencing. Short retaining walls can provide relatively maintenance-free barriers for reptiles, amphibians and small mammals.

Travel Distances: Large passage structures suitable for more mobile species may not have to be spaced as closely as passage ways designed for small mammals, amphibians and reptiles. A mixture of widely spaced large structures and more frequent small structures positioned to facilitate animal passage within designated “ connectivity zones” would likely represent a more cost effective strategy for mitigation than a series of large multi-species structures.

Some of the most effective techniques for facilitating wildlife movement (i.e. overpasses) are also quite expensive. A practical strategy for mitigating highway impacts on wildlife movement may dictate that expensive elements be reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitat, while inexpensive elements (amphibian and reptile tunnels) can be used at appropriate areas throughout the highway alignment. In developed areas, corridors and habitat connections may be readily apparent (figure 1). For highway projects affecting a significant amount of undeveloped land it may be necessary to conduct landscape analyses to identify "connectivity zones" for special mitigation attention.

Landscape analyses for the purposes of identifying "connectivity zones" may vary. An idealized approach would evaluate landscape features to determine the most valuable habitat for wildlife and wildlife movement (figure 2 & 3). Designation of these areas as "connectivity zones" along with a strategy for protecting significant habitat on both sides of the highway would provide the most effective mitigation. Alternatively, build-out analyses could be used to determine what connections would likely remain after an area is developed following highway construction (figures 4 & 5). Treating these areas as "connectivity zones" with the selective use of conservation easements and land acquisition to ensure proper connectivity, would be a less expensive form of mitigation. Mitigation planning based on both types of analysis may provide a practical and effective method for siting wildlife passage mitigation.

To mitigate highway impacts on wildlife we must focus both on reducing the impact of roadways on local populations and preserving ecological processes related to landscape continuity and metapopulation dynamics. Mitigation strategies that focus too much on preserving local populations may be too expensive to be fully implemented, given the large numbers of species involved. A practical strategy for mitigating highway impacts should first focus at the landscape level, using the most effective techniques available to maintain landscape continuity and metapopulation dynamics within designated “connectivity zones.” In addition to the maintenance of some level of ecosystem function, cost effective techniques should be practically employed throughout the highway alignment to maintain local wildlife populations.

In our opinion, a practical strategy for mitigating highway impacts on wildlife should include:

- Avoidance of highway fencing and Jersey barriers when not used in association with wildlife passage structures,
- Use of small (e.g. 2’x 2’) amphibian and reptile passages wherever roadways pass along the boundary between wetlands and uplands,
- Use of oversized culverts and expanded bridges at stream crossings,
- Selective use of viaducts instead of bridges at important stream or river crossings,
- Use of landscape-based analyses to identify “connectivity zones” where a variety of mitigation efforts can be concentrated to maintain ecosystem processes,
- Selective use of wildlife overpasses and large wildlife bridges within “connectivity zones,” and
- Monitoring and maintenance plans to ensure that mitigation systems continue to function over time and that knowledge gained from these projects can be used to further refine our mitigation techniques.

Conclusion

Traditionally, highway impacts on wildlife have been viewed in terms of road mortality and threats to selected populations of animals. Viewing this issue from a landscape ecology perspective, it is clear that highways have the potential to undermine ecological processes through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and metapopulation dynamics.

Many questions remain about how to design roads, highways, and wildlife passage structures that will effectively mitigate the impact of roadways on animal movements and wildlife populations. However, much has been learned from projects around the world that can guide current approaches to mitigation. Through research, experimentation and the development of ecosystem-based mitigation strategies, we should be able to identify practical and reasonable approaches for mitigating road and highway impacts on wildlife communities and ecosystems.

We recommend the adoption of a concept in current use in the Netherlands, that of ecological infrastructure (Friedman, 1997). Transportation planners know that highway and railway systems must accommodate other elements of human infrastructure (water supply systems, sewer systems, electric and gas utilities). By defining networks of core areas and connectivity zones, biologists and natural resource planners can effectively define the ecological infrastructure for a region and then work with transportation agencies to ensure that transportation systems are designed to accommodate this ecological infrastructure.

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Figures

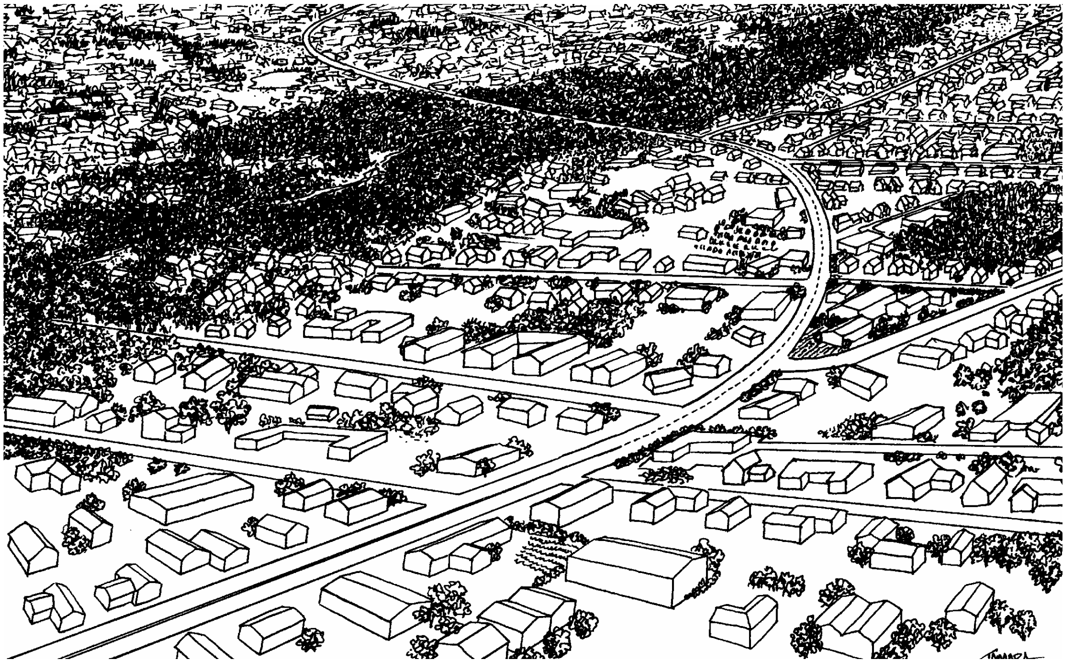

Figure 1. In developed landscapes connectivity zones may be readily recognized as remnant patches of habitat.

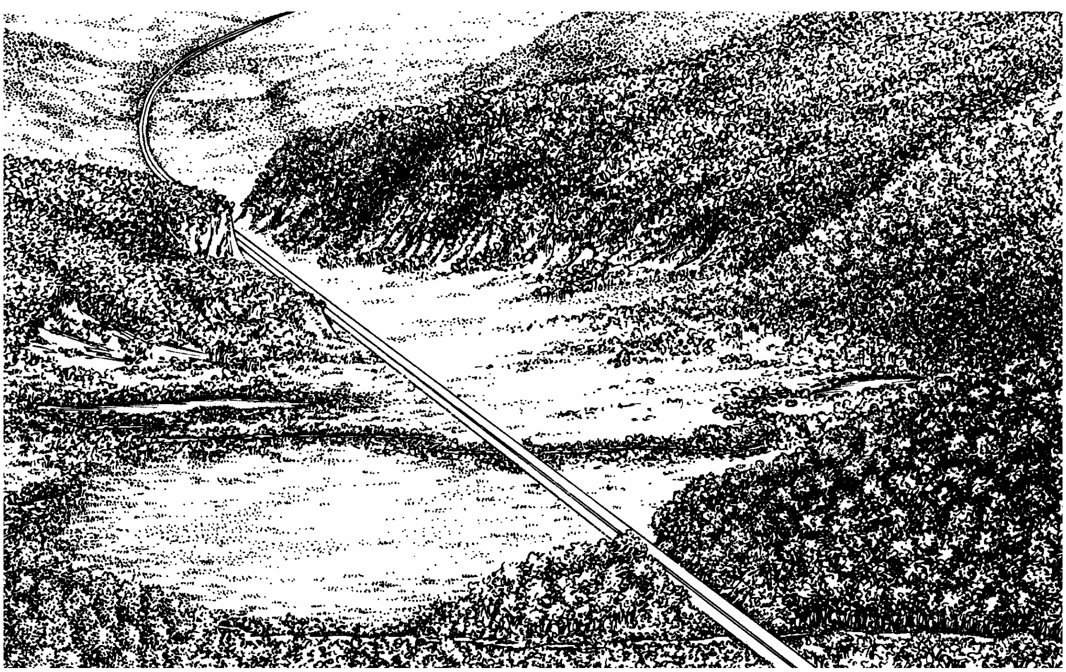

Figure 2. In undeveloped areas, landscape-based analyses can be used to determine connectivity zones and the placement of wildlife crossing structures.

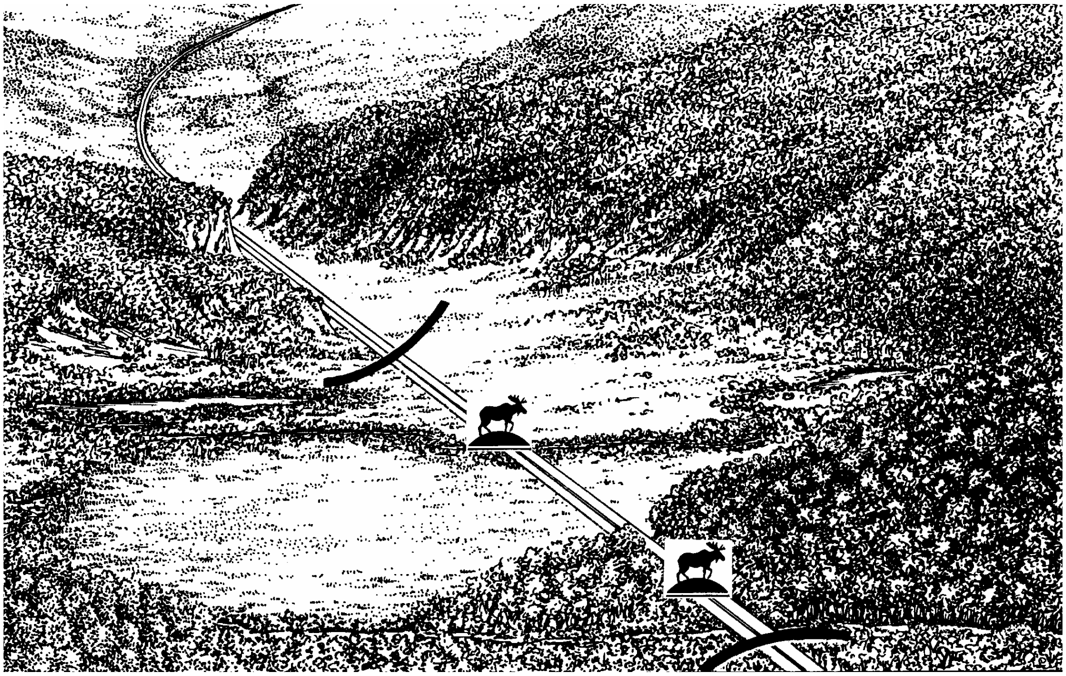

Figure 3. Landscape analyses based on ecological criteria can be used to select connectivity zones that reflect habitat preferences and movement patterns of target wildlife species.

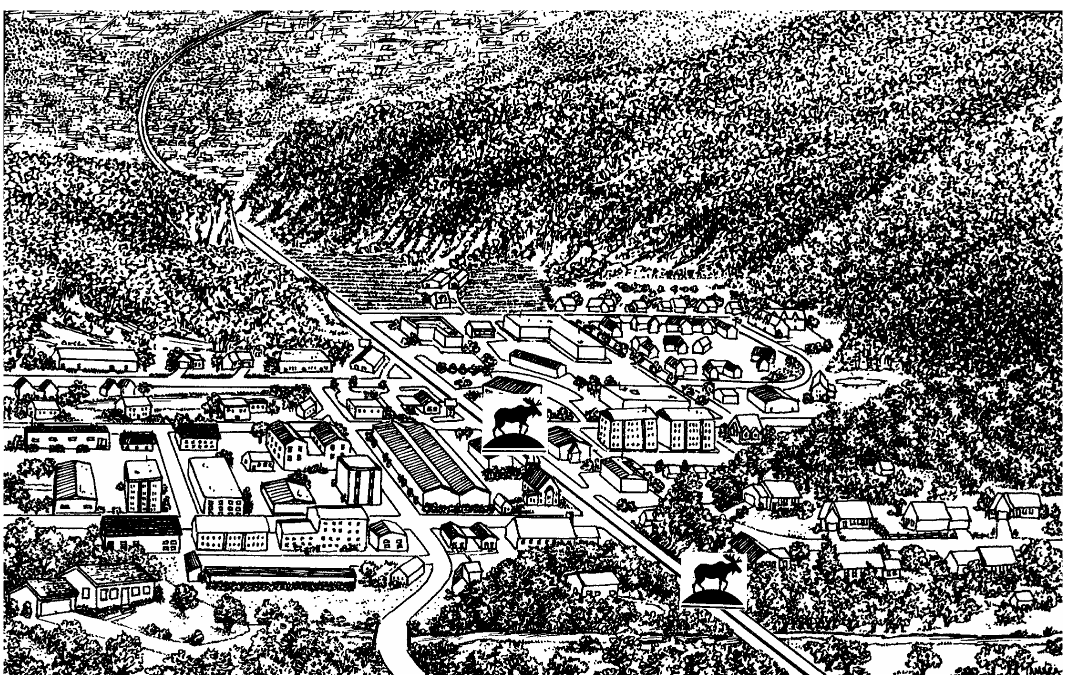

Figure 4. Wildlife crossing structures located solely on the basis of ecological criteria may become ineffective over time due to changes in land use.

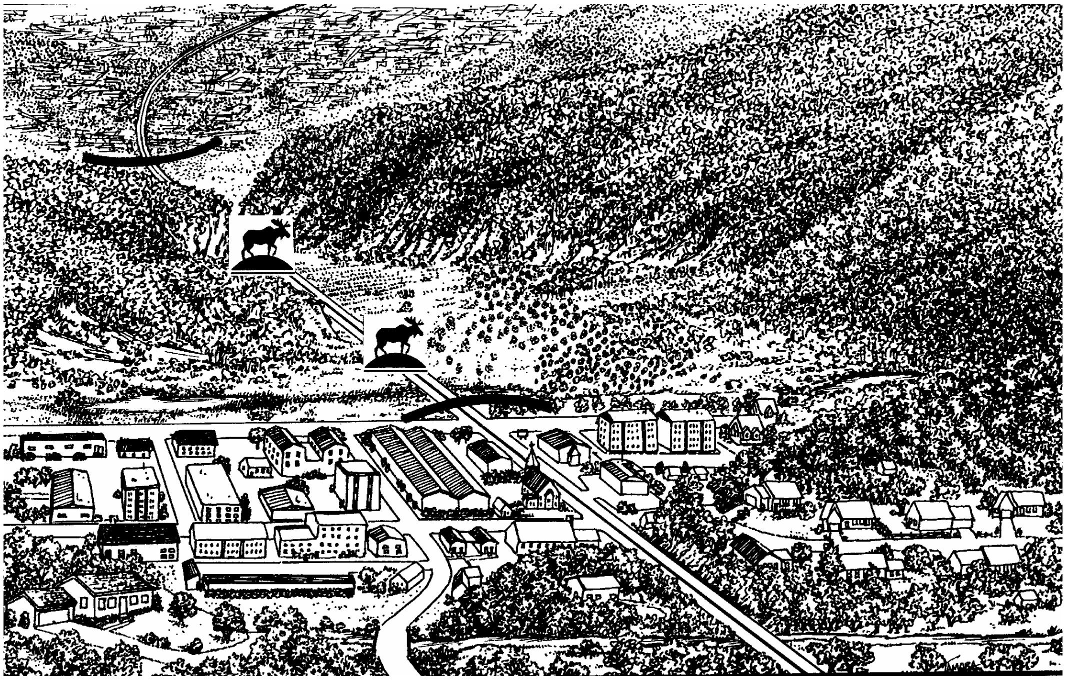

Figure 5. Use of ecologically based landscape analyses along with land use build-out scenarios may provide the most practical approach for identifying connectivity zones and determining the proper placement of wildlife crossing structures. Strategic use of land acquisition and conservation easements can enhance or preserve these connectivity zones.