# LITERATURE REVIEW PAPER

VENTURA 118 WILDLIFE CORRIDOR ASSESSMENT PROJECT

CALTRANS DISTRICT 7

EA NUMBER 223800

CONTRACT 43A0082

TASK ORDER 9

LSA

July 25, 2003

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## TASK ORDER 9

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# 1. INTRODUCTION

The California Department of Transportation (Caltrans) District 7 is conducting an environmental review on the effects of State Route 118 (SR-118) road improvements. The proposed project is located at Rocky Peak Road. The road improvements currently proposed are the eastbound off-ramp and the westbound on-ramp of Rocky Peak Road Overcrossing.

The environmental review process includes a wildlife corridor assessment, part of which is camera and track station monitoring survey at several passageways across SR-118. The monitoring is being conducted to survey the wildlife activity adjacent and through the SR-118 right-of-way. Another part of the wildlife corridor assessment includes reviewing scientific literature. Topics include the effects of transportation projects on large mammals and the mitigation for those effects, especially with regard to wildlife crossings, habitat corridors, and structural passageways. The literature review reports on the current knowledge of species requirements related to habitat corridors and passageways, which, in turn, can be used to develop minimum standards for wildlife crossings in Southern California and specifically the SR-118 road improvement project.

## A. PURPOSE

The purpose of this literature review paper is to:

- Report on the current state of knowledge on the subject of wildlife passageways through transportation rights-of-way;
- Describe the characteristics of the passageways and habitat corridors used by large mammals in Southern California;
- Summarize the known effects of road projects and land development to wildlife crossing function; and
- Provide guidance on the most appropriate planning, designing, construction, landscaping, mitigation, maintenance, and monitoring approaches to a functional wildlife corridor and passageways for large mammals through transportation rights-of-way.

The literature review provides background information pertinent to the following research questions:

- What constitutes a functional wildlife crossing across a transportation right-of-way?
- What large and medium-sized mammals (e.g., mountain lion, bobcat, mule deer, gray fox, badger, and coyote) use wildlife crossings through transportation right-of-way? What are the species-specific preferences of functional wildlife crossings?
- What are the constraints to wildlife movement through wildlife crossings?

- What enhancements would be most valuable for maintaining or promoting wildlife use of an existing wildlife crossing?
- What are the effects (direct, indirect, and cumulative) of land use changes, urbanization, and road projects to wildlife crossing viability?
- What are appropriate mitigation measures, suggested monitoring methods, and compatible highway maintenance activities for ensuring a constructed wildlife crossing will be functional?

## B. DEFINITIONS

The following terms are defined for the sake of clarification:

| | |
|---|---|
| Home Range | An area that an animal may use to forage, hunt, or otherwise occupy but not actively defend from competitors. |
| Minimum Habitat Area | The amount of undeveloped land that can sustain a viable population of a target species for at least 100 years. |
| Overpasses | Could either be a road over-crossing or a vegetated overpass. In Europe, the vegetated overpass is also called an "ecoduct" or "green bridge." |
| Species Density | The number of individuals per unit area. |
| Target Species | The literature review focused on some of the large and medium mammals known to occur in Simi Hill and Santa Monica Mountains. These species are mountain lion, bobcat, gray fox, coyote, mule deer and badger. |
| Underpass | Could be a corrugated pipe culvert, reinforced concrete pipe or box culvert, or bridge. Underpasses can be developed with a dirt or paved road or be a natural dry canyon or stream channel. |
| Viaduct | A very long and elevated bridge that spans an entire valley, canyon, or multiple streams or river channels. |
| Wildlife Corridor (Linkage) | A strip of habitat that connects two otherwise separated larger habitat areas (Santa Monica Mountains Conservancy [SMMC] 1990). |
| Wildlife Crossing | A specific location along a transportation right-of-way where a strip of habitat and a passageway exist together and could potentially function as a pathway for wildlife to cross the right-of-way. |
| Wildlife Passageway | A term used in this review to identify the actual structure used by wildlife to cross a transportation right-of-way. Passageways can either be underpasses or overpasses (Jackson and Griffin 1998). |

# 2. DISCUSSION

## A. WHAT CONSTITUTES A FUNCTIONAL WILDLIFE CROSSING ACROSS A TRANSPORTATION RIGHT-OF-WAY?

This section will review the literature findings as related to the general requirements of wildlife crossings and passageways. The following section will discuss the species-specific wildlife crossing and passageway preferences:

A wildlife crossing is considered functional when it meets the following three criteria:

- It reduces roadkill after construction;
- It maintains habitat connectivity and the target species is present on both sides of the right-of-way; and
- It allows genetic interchange to occur (Foreman and others 2003).

A wildlife corridor is functioning over a longer period of time when:

- Species fitness in ensured (genetic exchange, no genetic drift, no skewed sex ratios);
- Juveniles are successful in dispersing across the right-of-way; and
- Normal ecological processes are occurring (Foreman and others 2003).

Before a wildlife habitat crossing can be functional, there must be sufficient habitat present on either side of the transportation right-of-way to support a population of the target species. Creating a functional wildlife crossing for large mammals entails wildlife conservation planning on a regional scale. Conservation includes protecting large habitat reserves and smaller interconnected protected areas, and using large carnivores as the planning focal species (Hunter 1999). In addition, planning needs to consider how the wildlife will get to the crossing from known breeding and foraging or hunting areas (Federal Highway Administration [FHWA] 2000a).

Using a generalized strategy in wildlife corridor and crossing planning, the target species is typically an umbrella species. An umbrella species is a species whose protection is expected to award benefits upon the greatest number of species (Beier and Loe 1992). An ideal umbrella species is a species that also has the greatest need for a wildlife corridor. In Southern California, the mountain lion is the ideal umbrella species used for regional habitat conservation and wildlife corridor planning because of its large home range requirements and high sensitivity to human activities (Beier 1995). More details on the habitat requirements of the mountain lion are discussed in the following section.

Several factors of a corridor design must be addressed in order for a wildlife corridor to continue to function under climatic fluctuations, natural events such as fire or flood, and land use changes. These factors are:

- Protecting a diversity of habitats;
- Protecting areas of rich biotic diversity;
- Distributing the habitat types along the length of the wildlife crossing or perpendicular to the transportation right-of-way;
- Implementing long-term management that mimics natural events; and
- Eradicating exotic and invasive plants (LaBaree 1992).

The Florida Department of Transportation has developed a decision-based GIS computer model for road improvement projects (Smith and others 1999). Analysis of the relative impact of road projects to wildlife conservation was based on several data categories. Information analyzed included:

- Chronic roadkill sites;
- Known regional migration/movement routes;
- Identification of hot spots for focal species;
- Landscape linkages (existing habitat greenways);
- Presence of listed species;
- Identification of strategic habitat conservation areas;
- Riparian corridors;
- Core conservation areas;
- Presence of geographically separated ecological resources required for a species to complete its life history;
- Public lands; and
- Potential for development as a road project.

Foreman and others (2003) stated that a wildlife crossing should be placed in a location where animals are known to cross naturally. However, because animal movement patterns can change, it may be best to place the wildlife crossing between high quality habitat areas and away from human activities. Typically, roadkill, radio-telemetry/GIS monitoring and tracking studies are conducted to determine the movement patterns of the target species. Movement patterns of many wildlife species follow drainages, topography, and preferred habitat type (Henke and others 2002).

The wildlife crossing must be wide enough to meet the habitat and cover preferences of each target species. Preferred habitat type(s) must be present on either side of the passageway (Ng 2000). Conserved habitat areas should encompass watersheds and maintain contiguity of riparian habitats

(Radtke 1993). A minimally sized wildlife crossing would be at least 152 meters (500 feet) in width (Beier and Loe 1992) to allow for a wide range of animals to move through. Viaducts may be the most cost-effective type of wildlife passageway after considering the cost of assessing, permitting, constructing, and monitoring fill or placement of structures across multiple topographic features and biologically sensitive areas (Evink 2002). These structures, viaducts, and bridges have been called the "high and wide" type of wildlife crossing in the literature. In areas where larger crossings are not feasible, then smaller culverts can be installed for additional connectivity and to encourage movement of smaller mammals and other wildlife species, such as reptiles, amphibians, and invertebrates. Smaller-sized crossings also provide protective cover for prey species.

Native vegetative cover can aid in the success of a wildlife corridor. Vegetation provides wildlife concealment, reduces traffic noise, and disrupts headlight glare (FHWA 2000a). Mountain lions may spend 24 hours in a "daybed" observing the activities near a road before attempting to cross the right-of-way (Beier 1995). Woodland habitat is required to provide cover for mountain lions crossing transportation rights-of-way. Shrubs, trees, stumps, and dirt berms can be used to reduce road noise and visibility. Noise level is recommended to be less than 60 decibels (Beier 1995) in a wildlife crossing. Fencing is recommended to reduce roadkill by preventing the wildlife from crossing the right-of-way at grade and to redirect movement to the passageways (Hartmann 2002). Fencing has been show to reduce roadkill be 80 percent in Banff National Park (Guterman 2002).

An underpass should contain the natural steam bottom or canyon and the natural vegetation should persist under the road. Although vegetation is important, it also must not be so dense in smaller underpasses and bridges that the view through the passageway is blocked (Hartmann 2002). Both prey and predator species prefer a clear view of the area on the opposite side of the road in order to anticipate the direction of travel and ascertain any potential threats. For large mammals (deer, mountain lion, and bear), underpasses should be trapezoid or canyon-shaped and at least 7.6 meters (25 feet) wide and 2.4 meters (8 feet) high and no more than 32.8 meters (100 feet) long (Evink 2002; Center for Transportation and the Environment [CTE] 2002). A mountain lion did use a box culvert that was 58 meters (190 ft) in length and 4.6 meters (15 feet) in height and width (Ng 2000) in the Simi Hills. Beier (1995) stated that mountain lions typically avoid culverts under freeways or two-lane roads. There were exceptions in his study. He observed one mountain lion out of nine included in a radio telemetry study repeatedly used a 3.3-meter (10 foot) wide and an estimated 40-meter (150-foot) long box culvert near the Santa Ana Mountains. In only two other instances, a mountain lion used a 1.8-meter (6-foot) wide and 9-meter (30-foot) long box culvert under a two-lane road. The remaining nine lions either avoided transportation right-of-ways, died from vehicle collisons, or crossed at grade or used bridge underpasses.

There are 50 known ecoducts, or green bridges, in the world. The ecoducts are 30 meters to 200 meters (98 feet to 656 feet) or wider (Foreman 2003). Ecoducts should at least be 200 meters (656 feet) wide to be functional for large mammals (Hartmann 2002; Evink 2002). Only six have been built in the United States. They are located in Florida, Hawaii, New Jersey, and Utah.

## B. WHAT LARGE AND MEDIUM-SIZED MAMMALS (MOUNTAIN LION, BOBCAT, MULE DEER, GRAY FOX, BADGER, AND COYOTE) USE WILDLIFE CROSSINGS THROUGH TRANSPORTATION RIGHTS-OF-WAY? WHAT ARE THE SPECIES-SPECIFIC PREFERENCES OF A FUNCTIONAL WILDLIFE CROSSING?

A variety of animals has been known to use wildlife crossings through transportation corridors. Movement patterns of many wildlife species seem to be associated with drainages, topography, and habitat. Some preferences are not species-specific. For example, large mammals (e.g., mountain lion, bobcat, mule deer, gray fox, badger, and coyote) select structural openness. These species prefer to have the ability to see an entrance and exit clearly and to be able to see through the passage. Below is a discussion of each species known to use wildlife crossings and its preferences for a functional wildlife corridor. Tables A and B summarize the various large mammal home range sizes, minimum preserve areas, wildlife corridor sizes, crossing areas, and passageway dimensions.

### Mountain Lion (*Felis concolor*)

Mountain lions are the most effective indicator species to evaluate the degree of functional landscape-level connectivity, low to moderately fragmented landscapes, and a valuable focal species in larger more intact habitat blocks (Crooks 2001). This is due to their high sensitivity to loss and/or fragmentation of habitat.

Mountain lions (also known as cougars, pumas, or panthers) require large home ranges and abundant supplies of preferred prey (deer). The mountain lion requires habitat patches of 1,000-2,200 square kilometers (386-850 square miles, 247,000-544,000 acres) to maintain a population of 15-20 mountain lions (Beier 1992). In regions where immigration is possible, meaning there is extensive contiguous habitat areas, minimum habitat patch size could possibly be 600-1,600 square kilometers (232-618 square miles, 148,224-395,264 acres) (Beier 1992). A male lion requires a home range of approximately 787 square kilometers (304 square miles) and a female lion requires approximately 265 square kilometers (102 square miles) (Hunter 1999). Beier (1995) found that dispersing juvenile male mountains lion home range was an average 250 square kilometers (96 square miles) and juvenile female home range was 75 square kilometers (29 square miles).

As a large carnivore, mountain lions will use corridors and peninsulas of habitat within urban areas. The habitat areas must not be lighted at night and accessible, not restricted by buildings or roads. Harrison (1992) generically suggested that a mountain lion corridor should have a minimum width of 12 kilometers (5.5 miles). Beier (1995) observed mountain lions using wildlife corridors with golf courses, adjacent commercial and residential development, recreational trails, and major freeways.

Mock et al. (1992) found that mountain lions would use crossings 100 to 160 meters (328 to 525 feet) wide if not longer than 500 meters (1,640 feet). Beier (1995) found that a greater width, at least 400 meters (1,312 feet), was required for wildlife crossings of greater length but no longer than 7 kilometers (4.4 miles). The most probable movement routes are canyon bottoms and ridgelines free of artificial light sources. Juvenile mountain lions dispersing at night did not have any aversion to parked vehicles, recreational trails or dirt roads. The lions will also pass close to isolated buildings with no outdoor lighting. They are not sensitive to recreational activities such as hiking, bicycling, and horseback riding (Clevenger and Waltho 2000). Crossing locations need to have a clear view of the opposite side of the roadway.

## TABLE A – MINIMUM HABITAT REQUIREMENTS AND WILDLIFE CORRIDORS AREAS FOR LARGE MAMMALS OF SOUTHERN CALIFORNIA

| Species | Home Range Area | Density | Minimum Habitat Area | Minimum Wildlife Corridor |
|---|---|---|---|---|
| **Mountain Lion** | | | | |
| Sq. km | 250-787 | 0.03 lion | 1000-2,200 | 23 |
| Sq. mi. | 96-304 | 0.07 lion | 386-850 | 8.9 |
| Hectares | 2,500-787,000 | | 10,000-220,000 | 2,300 |
| Acres | 61,440 – 194,560 | | 247,000-544,000 | 5,681 |
| Minimum Width | | | | 12 km (5.5 mi.) |
| **Bobcat** | | | | |
| Sq. km | 0.24-5.6 | 1.3 bobcats | 10 | 1.8 |
| Sq. mi. | 0.1-2.2 | 3.4 bobcats | 3.9 | 0.7 |
| Hectares | 24-560 | | 1,000 | 180 |
| Acres | 6.4-1,408 | | 2,470 | 445 |
| Minimum Width | | | | 2.5 km (1.6 mi.) |
| **Coyote** | | | | |
| Sq. km | 0.7-12 | 0.3 coyote | | 0.1 |
| Sq. mi. | 0.3-4.6 | 0.8 coyote | | 0.04 |
| Hectares | 70-1,200 | | | 10 |
| Acres | 192-2,944 | | | 25 |
| **Gray Fox** | | | | |
| Sq. km | 0.22-1.87 | 5.2 foxes | | |
| Sq. mi. | 0.08-0.7 | 13.5 foxes | | |
| **Badger** | | | | |
| Sq. km | 1.4-3.7 | | | |
| Sq. mi. | 0.5-1.4 | | | |
| **Mule Deer** | | | | |
| Sq. km | 1-3 | 7-23 deer | | |
| Sq. mi. | 0.4-1.1 | 18-60 deer | | |

**Sources**: Beier 1992, Beier 1995, Crooks 2001, Evink 2002, Foreman and others 2003, Harrison 1992, Hunter 1999, Lyren and Crooks 2002, Ng 2000, Riley and others (year unknown), Sauvajot and others 2000.

## TABLE B – WILDLIFE CROSSINGS AND PASSAGEWAY DIMENSIONS FOR LARGE MAMMALS OF SOUTHERN CALIFORNIA

| Species | Minimum Passageway Size | Minimum Wildlife Crossing Area |
|---|---|---|
| **Mountain Lion** | 2.6 by 3.3 meters wide by 200 meters in length<br>(8-10 feet high by 10 wide by 656 feet long ) | 400 meters wide by 7kilometers long<br>(1,312 feet wide by 4.4 miles long)<br>If narrow, then must be short; 100-160 meters wide by 500 meters long (328 to 525 feet wide by 1,640 feet long) |
| **Bobcat** | 1.8 meter culvert by 33 meters long<br>(6 feet by 100 feet long);<br>3.3 meter box culvert by 70 meters<br>(10 foot box culvert, 230 feet long) | |
| **Coyote** | 1.8 meter culvert by 33 meters long<br>(6 feet by 100 feet long);<br>3.3 meter box culvert by 60 meters<br>(10 foot box culvert, 200 feet long) | |
| **Mule Deer** | 5 meter box culvert, 61meters long<br>(15 foot box culvert, 200 feet long) | |

**Sources**: Beier 1992, Beier 1995, Crooks 2001, Evink 2002, Foreman and others 2003, Harrison 1992, Hunter 1999, Lyren and Crooks 2002, Ng 2000, Riley and others (year unknown), Sauvajot and others 2000.

A mountain lion will not use a passageway if its normal travel pattern does not cause it to encounter a passageway. A natural travel route will be used, even if the habitat conditions are sub-optimal. An example of this behavior is the use of State Route 91 Coal Canyon bridge by a single mountain lion. (Beier 1995). This crossing is degraded due to two golf courses and a stable. Dispersing lions used wildlife corridors and crossings that are located along obvious travel routes (stream scours, ridgelines, dirt roads, and trails) that have ample woody cover without dense shrub understory, lack artificial outdoor lighting, and have low human population density (Hunter 1999).

Mountain lions will cross high-speed and paved roads at grade in order to disperse into other habitat areas. When dispersing into new territory, a lion will orient to unlit areas. Therefore, new crossings and passageways can be discovered and used by juveniles, if the site conditions encourage the lion movement through the corridor to the constructed passageway.

Underpasses have proven to be a vital link in preventing roadkill of the federally endangered Florida panther (*Felis concolor coryi*) (FHWA 2000d). Bridge underpasses are preferred over pipe or box culverts (Beier 1995). In Beier's (1995) study, the majority of the transportation right-of-way crossings by dispersing juvenile mountain lions traveled under bridges. In the Santa Ana Mountains, one lion did use a 1.8-meter (6-foot) box culvert under a two-lane road, but typically the two-lane roads were crossed at grade. Juvenile mountain lions used a 2.6 by 3.3-meter (8 by 10-foot) box culvert that was 200 meters (656 feet) in length. More commonly, adult mountain lions crossed under bridges.

### Bobcat (*Lynx rufus*)

As with the mountain lion, habitat loss and fragmentation threaten the bobcat. This includes the loss of large, relatively undisturbed blocks of habitat and the absence of adequate linkages between blocks of habitat. A bobcat's daily movements range from approximately 1 kilometer (0.6 mile) to 10 kilometers (6.2 miles) (University of California 2001). Male bobcat home ranges are generally bigger than those of females. Bobcat home ranges average seasonally for males and females at 1.7 square kilometers (0.6 square miles) with a range of 0.57 to 2.4 square kilometers (0.2 to 1.0 square miles) (Sauvajot and others 2000). Male home ranges increase in size within urban areas; however, these home ranges are still composed of at least 70 percent natural habitat area.

Bobcats are susceptible to negative impacts of highways and they will use bridges, modified culverts, unmodified culverts, and vegetation cover planted within 100 meters (328 feet) of the highway in the same proportion as the culvert availability (Cain and others 1999). Bobcats have used culverts measuring 1 to 3 meters (3 to 9 feet) in width and 50-65 meters (164 to 213 feet) in length. In addition, fencing along roadways near movement linkages to funnel bobcats into the wildlife crossing and reduce vehicular collisions should be used (University of California 2001). Bobcats require a minimum corridor width of 2.5 kilometers (1.6 miles) (Harrison 1992). If a constructed culvert will be or is being used by mule deer, then it is highly likely that bobcat will also use the same wildlife corridor.

### Mule Deer (*Odocoileus hemionus*)

Deer are the preferred prey of most large to small cats and coyotes. Mule deer will avoid roads and/or areas that are within 20 meters (66 feet) of roads as well as heavily traveled roads and roads that are adjacent to human habitation. Fencing placed next to highways can cut hoofed animal deaths by 96 percent. A 35-month study in Canada that included monitoring animals back-and-forth movement through the crossing structures showed that both ungulates (hoofed animals) and carnivores were using the wildlife crossings (FHWA 2000a). Deer prefer those crossings that are less frequent passages for their predators. Human activity near the wildlife passages can affect the mule deer usage of the facility.

A wide variety of culverts, overpasses, and underpasses has been successful in providing wildlife crossings for mule deer. In Banff, underpasses as small as 26 meters long by 4 meters wide by 2.5 meters high (85 feet long by 13 feet wide by 8.2 feet high) were used. In Colorado, deer used a 3 by 3 by 30-meter (10 by 10 by 100-foot) underpass when a nearby bike path was screened from their view (Evink 2002). As a standard, deer require crossings at least 7 meters (23 feet) wide and 2.4 meters (8 feet) high (Foreman and others 2003). The crossing success also depends upon the control of human activity.

As road density increases to six miles of road per square mile, mule deer habitat falls to zero. Deer will tend to avoid areas within ¼ - ½ mile of roads, depending on traffic, road quality, and the density of cover (Noss 2002). A recommended minimum wildlife corridor width is 0.6 kilometer (0.27 mile) (Harrison 1992).

### Coyote (*Canis latrans*)

Coyotes occur in almost all habitat types. They have adapted into urban predators that travel large distances and have large home ranges. Coyotes are found in most open habitats and are tolerant of human activity. They adapt and adjust rapidly to changes in their environment (California Department of Fish and Game [CDFG] 1990). Coyotes are useful as a focus species for wildlife crossings that are still functioning in highly urbanized areas. Male coyote home ranges are reported at 8 to 80 square kilometers (3 to 31 square miles) and overlap. For female coyotes, home ranges vary from 10 to 100 square kilometers (4 to 39 square miles).

Coyotes are using the cement channel of Los Angles River to travel between the only two semi-natural areas in the vicinity; Sepulveda Basin and a local community college campus (Riley 2003). Coyotes prefer larger box culvert and bridge underpasses as passageways under roads. Ideally, the passageways are open and short. The height and width should be at least 2.5 meters (8 feet) and no longer than 100 meters (328 feet).

Coyotes use roadways to search for prey, but the activity may not be strictly associated with small-mammal density in the right-of-way. Rather coyotes may use roadways simply for ease in movements and vulnerability of prey crossing a road (e.g., mice crossing roads at night) (Gosslink and others 2003).

### Gray Fox (*Urocyon cinerioargenteus*)

The gray fox is also a known urban predator that regularly uses underpasses. It is often seen within 50 meters (164 feet) of urban development, and also inside urban areas. Home range area varies from 0.22 to 1.87 square kilometers (0.08 to 0.7 square miles) (CDFG 1990). When gray foxes use a wildlife crossing structure, usually the narrower and more fragmented underpass sites will be chosen (Ruediger 1998).

Gray foxes are not commonly observed during tracking surveys in Southern California, possibly because of competition from coyotes, which also travel the passageways. Coyote populations have increased across North America over the past few decades (Gosslink and others 2003). Coyotes affect gray fox populations by competitively excluding foxes temporally, spatially, and by direct mortality (Gosslink and others 2003). Coyotes are known to kill high numbers of gray foxes (Kamler and others 2003). In addition, coyotes also compete with bobcats, raccoons, badgers, and striped skunks.

Passageway dimensions preferred by gray fox were not found in the literature reviewed, but it can be expected that they would use passageways similar to those used by bobcats and coyotes, provided that they have the opportunity to avoid these species in the corridor and passageway. Dense cover should be provided in the wildlife corridor to conceal prey species from predators and to minimize interspecies interactions.

### Badger (*Taxidea taxus*)

This medium-sized carnivore's use of tunnel and culvert crossings has proven to be successful in lowering roadkill rates. Green space and habitat protection are also successful measures. Home range of female badgers in Santa Monica Mountains National Recreational Area varies from 1.4 square kilometers (0.54 square mile) to 3.7 square kilometers (1.4 square miles). Steep topography in coastal sage scrub, chaparral, and grassland habitats are preferred habitat (Lupis and others 1999).

A significant decrease in badger mortality is seen after tunnels are constructed allowing the badgers to cross under the roads. In combination with fence installation, tunnels and habitat protection has resulted in nearly doubling the local badger populations in some areas (FHWA 2000d).

## C. WHAT ARE THE CONSTRAINTS TO WILDLIFE MOVEMENT THROUGH WILDLIFE CROSSINGS?

The use of a crossing by wildlife is affected by many complex factors (Clevenger 2002). Factors include:

- The site characteristics of the wildlife corridor;
- Physical structure of the passageway;
- Location;
- Time lag associated with species becoming aware of the crossing existence, then habituation by adults and learned use by offspring;

- Traffic noise;
- Light spillage;
- Human activities in the crossing;
- Changes in land use and development patterns;
- Changes in species populations and movement patterns, and interspecies competition;
- Fluctuations in food supply;
- Climate extremes; and
- Natural events, such as fire or flood.

There must be suitable habitat of appropriate extent within the wildlife corridor for a species to use the wildlife crossing. The corridor must be large enough for the species to occupy the corridor permanently, as part of its home range, thereby making it likely that the species will use the wildlife crossing. Recommended minimum corridor width for bobcats is 2.5 kilometers (1 mile) and the minimum width is 12 kilometers (5.5 miles) for mountain lion (Harrison 1992).

The width of a wildlife crossing is related to its length. A functioning crossing can be narrow, if it is short (Harrison 1992). Also, the short and narrow crossings will only be effective if wildlife movement is funneled to the passageway by fences (Jackson and Griffin 1991). The bottom of the crossing should be a natural surface with rows of stumps or boulders to serve as cover for small wildlife species. Riprap placed at the passageway openings and on the adjacent slopes will deter animal use.

The proximity of development to a canyon edge and mouth will hinder wildlife movement and passageway use (SMMC 1990). Artificial light will deter wildlife species that are sensitive to human activities. The availability of ambient light in a passageway encourages wildlife use. A bridge is recommended to have an open median, if it is high enough to have low noise levels and if it is very long (more than 30 meters/100 feet). Noise levels should be less than 60 decibels. Vegetation, dirt berms, and debris piles can be used to block noise from roads. Deep water continuously present in the passageway will deter wildlife use.

Ideally, bigger is better when designing underpasses. Overpasses are more accommodating to more species than underpasses (Jackson and Griffin 1998). Overpasses are less confining, quieter, and have similar vegetation and ambient conditions to the surrounding habitat.

Controlling human activities is a significant factor in the success or failure of wildlife crossings and passageways (Clevenger 2002). Screening the views of trails or roads from the wildlife crossings will encourage wildlife use. For example, deer began to use a wildlife crossing only after a nearby recreational bike trail was screened with a planted row of vegetation.

## D. WHAT ENHANCEMENTS WOULD BE MOST VALUABLE FOR MAINTAINING OR PROMOTING WILDLIFE USE OF AN EXISTING WILDLIFE CROSSING?

The size of the passageway in a wildlife crossing is a limiting factor in whether the passageway would be used by a particular wildlife species. The actual passageway may be too small, but the wildlife species may attempt to cross the road at grade, if the wildlife corridor was suitable and enticed the animal to move through the corridor. Therefore, another key factor is whether the habitat conditions in the wildlife crossing are suitable. Preferred habitat must also be present within the wildlife crossing and ideally within the passageway. Specific enhancements can be implemented to improve a wildlife crossing to make it more appealing or enticing.

Wildlife species will prefer openness (size of the underpasses relative to the width of the roadway) to allow the animal to see the opposite end of a wildlife passage (Jackson and Griffin 1998). Even though openness is preferred, there should still be vegetation within the crossing to provide cover for smaller prey species. Also, dense vegetative cover must be present near passageways in order to provide vantage or observation points. Mountain lions may stay in one location for several hours assessing the area prior to entering the passageway or crossing the road (Beier 1999). Vegetation can also be used to reduce noise levels, block light spillage, and block the visibility of human activities (FHWA 2002d). A very important characteristic of functioning crossings and wildlife corridors in urbanized areas is the absence of artificial lighting in the remaining fragmented natural areas. Water guzzlers can be constructed near dry crossings or in wildlife corridors with limited water sources to encourage wildlife use of the corridor and passageway (Edelman 1991).

Underpasses at stream crossings still probably suffice for species that utilize riverine or riparian habitat. Proper drainage is important, because some wildlife species are less likely to use a corridor when it contains standing water (Jackson and Griffin 1998). Augmentations such as modified culverts with add-on shelves that run parallel to culvert in perennial drainage may be incorporated for small mammals and reptiles. An added concrete walkway that is 0.46 meter (1.5 feet) wide or a wet/dry culvert 0.4 to 2 meters (1.3 to 6.6 feet) in diameter (Evink 2002) will accommodate small mammals, reptiles, and amphibians accessing the culvert crossing. Shelf additions to the inside of the culvert, slightly above the water surface and parallel to the stream allow for wildlife to continue its path along the water. When the shelves are added to the culvert design before construction, the additional cost is minimal in comparison to the overall cost of the structure. (FHWA 2003). Stump piles placed under bridges to enhance movements of invertebrates, birds, small mammals, reptiles and amphibians will also improve corridor usage (Foreman and others 2003). Natural rock ledges along the inside of culverts are an asset for small mammals crossing highways.

Riprap placed at passageway openings will block access to a passageway for some large mammals, such as deer. Riprap should not be placed in front of or on the slopes adjacent to a passageway. If riprap is required, then it should be buried, back-filled with topsoil, and planted with native vegetation.

Fencing is recommended by several investigators and shown to reduce road mortality (Lyren and Crooks 2002, FHWA 2000b). Fencing is used to prevent animals from crossing roads, directing animals to cross at grade in specific locations, or to direct wildlife to overcrossings or undercrossings.

## E. WHAT ARE THE EFFECTS (DIRECT, INDIRECT, CUMULATIVE) OF LAND USE CHANGES, URBANIZATION AND ROAD PROJECTS TO WILDLIFE CROSSING VIABILITY?

### Direct Effects

A road project, urbanization, or any land use change typically results in a direct loss of habitat, degradation of habitat quality, habitat fragmentation, and reduced habitat access and wildlife population fragmentation. Road aversion and other behavioral modifications have a direct effect on the usage of wildlife crossing by some species. Other impacts include increased human exploitation, wildlife anthropic habituation, shifts in biodiversity, hydrological changes, and construction effects. Construction can affect water quality, cause erosion, and release road chemicals, salts, noise, light, petroleum, or hazardous materials into the environment.

Habitat fragmentation and population isolation is another direct effect of land changes and urbanization on wildlife crossing viability. Some animals will not cross barriers as wide as a two-lane road. Some small vertebrates and invertebrates will not cross even lightly used roads. Divided highways with a clearance of 90 meters (295 feet) or more may be as effective barriers to the dispersal of small mammals as water bodies twice as wide (Noss 2002).

Roads restrict movements within home range, define boundaries of home ranges, or form complete barriers to movement. Roads can also facilitate accidental translocation, wildlife pathways for foraging, dispersal corridors, migratory movements and population range expansion, as seen in the California pocket gopher (*Thomomys bottae*) (Bennett 1991) can also be direct effects of land changes, urbanization, and road projects.

### Indirect (Secondary) Effects

Secondary or indirect effects occur later in time or are physically removed from a project (Evink 2002). Indirect effects of land changes, urbanization, and road projects are things such as vehicle emissions (e.g., carbon, nitrogen, sulfur, carbon particles), and release of other pollutants such as oil droplets, car and tire parts, litter, lead compounds, and other gas additives and salt. Roads allow for access into wild areas by hunters, poachers, trappers, recreationists, and indigents. Roads are the precursors to human immigration, settlement, deforestation, and environmental change (Bennett 1991). Effects also include an increase in vehicle traffic and associated residential and commercial development, recreational access, forestry, and facilitation of human disturbance by improving accessibility of previously remote areas, ripple effects in adjacent areas, and effects into areas away from the road project.

Large mammals may continue to use a low-traffic road as a convenient way of travel or to feed on roadkill or small mammals in grassy road shoulders. Nevertheless, they are unable to maintain populations where road densities are high, because of the mortality rates with high vehicle speeds, legal or illegal hunting, or roadkill (Noss 2002). Also, the frequency of roadkill is higher on more remote and less frequently traveled roads than larger, more urban roads. This is because less road avoidance in remote locations increases the chance of wildlife being hit by a vehicle.

### Cumulative Effects

A cumulative effect is an impact on the environment resulting from incremental impact of the action when evaluated in combination with other past, present, and future projects. It also refers to effects which can increase over time and space (Evink 2002). The cumulative effects are defined by the spatial and temporal boundaries of the project and by the wildlife species of interest and their habitat requirements. Cumulatively, roads diminish the native diversity of ecosystems. Culverts, tunnels, underpasses, overpasses, and other wildlife corridor structures can lessen the impact that highways have on the wildlife (Noss 2002).

Examples of cumulative effects include:

- Increased repetitive and frequent impacts to wildlife and habitat due to the presence of the roads, greater fire frequencies, increased vehicle access, greater accessibility into remote areas for hunting and poaching, residential and commercial uses, recreational access, firewood gathering, and commercial forestry;
- Effects which increase in severity over time and space (any direct and secondary effect);
- Effects which alter the micro-ecological and macro-ecological structure and processes (habitat shifts, watershed alteration, and global climate change); and
- Population disruption: food web disruptions genetic flow shifts, local population extinction, metapopulation dynamics, and secondary extinctions.

## F. WHAT ARE APPROPRIATE MITIGATION MEASURES, SUGGESTED MONITORING METHODS, AND COMPATIBLE HIGHWAY MAINTENANCE ACTIVITIES FOR ENSURING THAT CONSTRUCTED WILDLIFE CROSSINGS WILL BE FUNCTIONAL?

The ultimate functionality of a wildlife corridor is determined by planning for the intended purpose of the passage, the target species, the road location and design, passageway dimensions, and the amount of post-construction funding available for habitat enhancement, monitoring, and maintenance (Foreman and others 2003).

Ensuring wildlife corridor functionality in order to lessen transportation effects on carnivores, Ruediger (2000) recommends:

- Development and implementation of national policies requiring the FHWA and land management agencies to address highway impacts on wildlife species; particularly carnivores;
- Better highway planning and coordination standards;
- Identification and management of critical land corridors;
- Implementation of highway crossing structures for wildlife; and
- Emphasis on highway research.

## Mitigation Measures

Mitigation measures are implemented as part of a road project in order to avoid, minimize, or compensate for impacts to wildlife. Avoidance measures with respect to wildlife habitat corridors include (Foreman and others 2003; Bennett 1991):

- Not building the road;
- Changing the proposed route to avoid wildlife corridor;
- Building the road underground (tunnel);
- Closing road to motor vehicles (permanently or seasonally); and/or
- Removing the road.

Examples of minimization measures are (Foreman and others 2003; LaBaree 1992; Bennett 1991):

- Constructing underpasses and overpasses;
- Building road below grade or adding soil berms to reduce noise;
- Making quieter road surfaces, motors, tires, and vehicle aerodynamics;
- Reducing pollution dispersal and using cleaner fuels;
- Restricting or screening human activities in wildlife corridor and crossing;
- Controlling use of trails by recreationists;
- Installing wildlife fencing; and/or
- Elevating roads over upland areas.

Compensation for impacts to wildlife habitat includes (Forman and others 2003; White and Ernst 2003):

- Restoring a wildlife crossing by retrofitting underpasses and overpasses;
- Enhancing adjacent habitat;
- Land acquisition or easements to ensure functional wildlife corridor;
- Establish additional wildlife crossings/corridors; and/or
- Replacing the same type of ecological conditions at more than 1:1 ratio.

Preserving a wildlife corridor between passageways is another mitigation measure to be considered. A wildlife corridor as part of a larger network of corridors provides secondary habitat. The locations of wildlife corridors near roads which allow public access and the number of places where roads intersect the wildlife corridor should be kept to a minimum. Highway departments should work closely with natural resource agencies in order to coordinate wildlife management with road construction and maintenance (LaBaree 1992).

Recommended mitigation measures in order to assure the long-term population viability of the mountain lion, badger, bobcat, mule deer, and gray fox in the Simi Valley and Santa Monica Mountains study area as outlined by Edelman (1991) are:

- Protection of all adequate remaining cross-freeway habitat linkages between Simi Hills, Santa Susana, Santa Monica, Los Padres, and Angeles National Forests;
- Protection of remaining continuous habitat in Simi Hills; and
- Protection of the multiple habitat linkages capable of facilitating movement of all the target species in habitat areas in the mountain ranges.

Efforts to implement these measures are, in part, underway. The boundaries of the Santa Monica Mountains National Recreation Area have been relocated by Congress in order to allow for expansion through future land acquisition in the Santa Monica Mountains (U.S. House of Representatives 2002).

Conditions suggested by Edelman (1991) to assure the long-term continuous use of wildlife corridors and crossings are:

- Development design should minimize ecosystem degradation;
- New development should be clustered adjacent to already existing development;
- Avoid all woodland, riparian, and wetland zones completely;
- Habitat restoration should not be used as a viable replacement mitigation;
- All new roads incorporate multiple adequately sized wildlife crossing structures; and
- No take of substantial grassland habitat.

The placement of fencing along right-of way boundaries aids in directing animals to suitable crossing locations and passageways (Evink 2002). One-way gates are not effective, but one-way escape chutes (ramps at grade) in combination with fences have been shown to work for antelope.

## Monitoring

Wildlife monitoring must be considered in the planning, construction, road improvements, and ongoing maintenance. Wildlife monitoring should include an inventory of species composition and further studies of composition, population dynamics, and movements of wildlife assemblages near roads (Bennett 1991).

Measuring the effectiveness of a wildlife crossing needs to be based on certain success criteria. Since the overall objective of the wildlife crossing is to increase the permeability of the road right-of-way, then success would be if the crossing reduces barrier effects and reduces roadkills (Foreman 2003). Monitoring the function of the wildlife crossing could include comparing roadkill frequency pre-construction and post-construction and monitoring the use of the crossing and habitat on both sides of the right-of-way-by adults, juveniles, previously absent species though the use of scent stations, cameras, and radio/GPS tracking.

## Maintenance

Along with mitigation measures, a maintenance protocol should be maintained to ensure the continued usage of the wildlife corridor/crossing/linkage or underpass/overpass. These measures should include structure maintenance and wildlife conservation.

Structure maintenance for underpasses should be done so that animals can see the other side. Overpasses require little to no maintenance. Fencing will need inspected and any damage repaired regularly (Evink 2002). Construction work and maintenance activities should be scheduled outside of the nesting and breeding season of sensitive species in the area of the wildlife crossing. Landscaping in the rights-of-way should consist of locally occurring native plants. Clearing the road shoulders should be done to reduce roadkill by increasing visibility and driver response time (Evink 2002).

# 3. CONCLUSION

Growth is inevitable. With growth comes more roads and, with those roads, consideration to the wildlife it will affect is a growing concern for managers, engineers, biologists and ecologists. Planning, mitigation, maintenance, and monitoring are the keys to an effective plan for wildlife crossings.

A functional wildlife crossing will (1) reduce roadkill after construction, (2) maintain habitat connectivity and allow target species to be present on both sides of the right-of-way, and (3) allow continued genetic interchange. A wide variety of animals can and will use a well-designed wildlife crossing. There must be sufficient habitat on both sides of the transportation right-of-way to support a population of the target species. The crossing should be placed within a wildlife corridor, a location where animals are known to cross naturally or in an area of extensive high quality habitat. The wildlife crossing must be wide enough to meet the habitat and cover preferences of the target species. A minimum width of a wildlife crossing would be 152 meters (500 feet). Passageways, ideally, should be "high and wide." In feasible locations, such as level topography or a ridge, wildlife overpasses or greenways are preferred to undercrossings.

As an umbrella species, the mountain lion habitat requirements would encompass the habitat requirement of many other wildlife species. Mountain lion home ranges can be as large as 82,880 hectares (204,800 acres) composed of habitat patches no less than 1,000 hectares (2,470 acres). Mountain lions have used wildlife corridors 400 meters (1,312 feet) wide and less than 7 kilometers (3.2 miles) in length. There must be suitable habitat of appropriate extent within the wildlife corridor for a wildlife species to use the wildlife crossing. The corridor should actually be large enough for an individual to permanently occupy the corridor, thereby making it likely that the species will use the wildlife crossing. Recommended minimum corridor width for bobcats is 2.5 kilometers (1 mile) and, for mountain lion, the width is 12 kilometers (5.5 miles).

Using animal behavior to help design wildlife crossing structures is a successful way to ensure structures will be used by their intended design species. Taking into consideration the target species habitat preferences increases the chances of the wildlife corridor's success. As observed in the Santa Ana Mountains, passageways used a mountain lion had been as narrow as a 1.8 meters (6 feet) box culvert when no more than 15 meters (50 feet) in length. Juvenile mountain lions used a 2.6 by 3.3-meter (8 by 10-foot) box culvert that was 200 meters (656 feet) in length. More commonly, adult mountain lions crossed under bridges.

Enhancements to a wildlife passage can be added once the size and location are chosen. Improvements will aid in other species that normally would not use a corridor to gain access to it. Enhancements include revegetation with native plants, relocating hiking trails, discouraging human intrusion, and providing various habitat within a crossing. Habitat enhancements within a crossing could also include concrete or natural rock ledges along the inside of culverts, which has proven to be an asset for small mammals crossing highways, and brush or stump piles to serve as cover.

In considering the construction of wildlife crossings, the direct, indirect, and cumulative effects of the transportation project must be taken into consideration. Primary direct effects are:

- Direct loss of habitat;
- Degradation of habitat quality;
- Habitat fragmentation; and
- Reduced habitat access and population fragmentation.

Fragmentation, isolation of populations, and the restriction of movement within home ranges are other considerations during planning, mitigation, and monitoring of a wildlife crossing. Most wildlife species prefer travel away from human activities. Although in areas with dense vegetation, large mammals will use hiking trials and dirt roads at night when humans are not present. Attention should be given to prevent artificial lighting from spilling into wildlife, corridors, crossings and passageways. Underpasses and overcrossings should be left dark to encourage wildlife use.

Indirect effects are more difficult to predict. These occur later in time, well after the construction of the wildlife passage. Indirect effects include land use changes, increased human encroachment and access, pollution, noise, and litter. As with the direct effects, steps can be taken to lessen the impacts. Road improvements are usually implemented to accommodate existing vehicle use and development or for planned and proposed land use changes and anticipated future traffic volume. Future land use changes that are facilitated by the road project need to be considered as part of the cumulative impact analysis.

Mitigation measures are implemented as part of a road project in order to avoid, minimize, or compensate for impacts to wildlife. Mitigation can include not building the road, relocating the road; restricting or screening human activities in wildlife corridor and crossing; installing wildlife fencing to reduce roadkill; making sure that all new roads incorporate multiple adequately sized wildlife passageways; or retrofitting new passageways under existing roads.

Monitoring is an important to the planning and after construction of the project. Monitoring is required to evaluate the optimal location for a passageway and to evaluate the function of the wildlife crossing.

Maintenance of any and all structures within the wildlife passageway must be done on a regular basis to ensure the ongoing success of the wildlife crossing. Maintenance needs to be included in planning as well as in mitigation measures. Maintenance operations and timing may need to modified in order to minimize impacts to wildlife species and habitat areas.

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