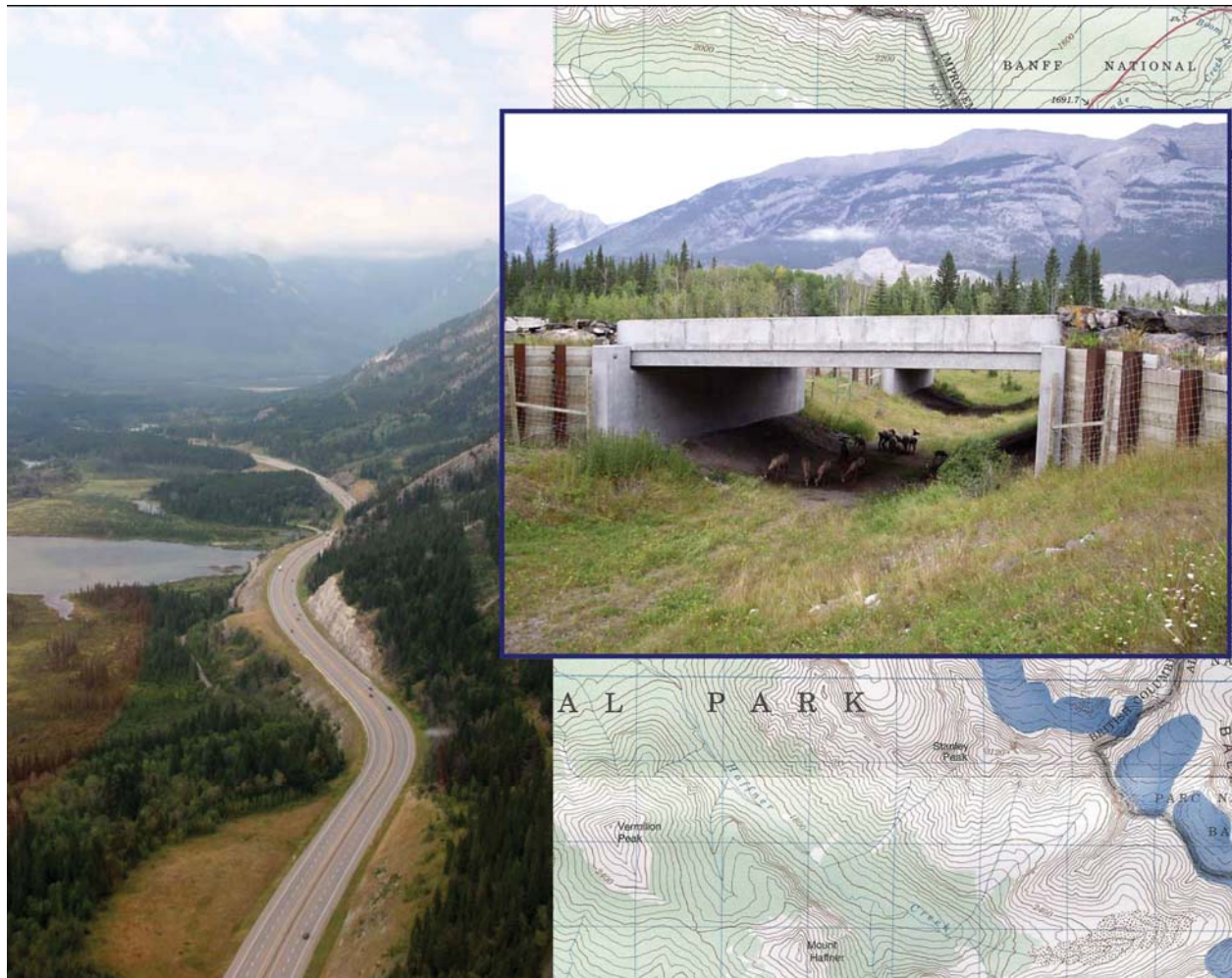

WILDLIFE CROSSING STRUCTURE HANDBOOK

Design and Evaluation in North America

Publication No. FHWA-CFL/TD-11-003

March 2011



U.S. Department
of Transportation
**Federal Highway
Administration**



Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228

FOREWORD

The Federal Highway Administration (FHWA) encourages programs that protect both wildlife and roadway users when the two groups eventually interact. An ever increasing human population demands safe and efficient access to their facilities, but this often comes with the need to mitigate the compromises to the animal habitats. Safety of drivers and preservation of animals are important components that when they successfully mesh we achieve major program goals for improved safety, enhanced livability, and protection of the environment.

This FHWA report called the *Wildlife Crossing Structure Handbook* offers key background information on defining the overall wildlife-vehicle interaction problem, the needs to be addressed, and offers a multitude of tangible solutions to plan, design, construct, monitor and maintain effective critter crossings. This handbook is for all transportation, environmental, wildlife resource, and stakeholder officials who strive to preserve and reweave safe corridor passages for animals and vehicle travelers.



F. David Zanetell, P.E., Director of Project Delivery
Federal Highway Administration
Central Federal Lands Highway Division

Notice

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement

The FHWA provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Technical Report Documentation Page

1. Report No. FHWA-CFL/TD-11-003	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle <i>Wildlife Crossing Structure Handbook Design and Evaluation in North America</i>		5. Report Date March 2011	
		6. Performing Organization Code	
7. Author(s) Anthony P. Clevenger and Marcel P. Huijser		8. Performing Organization Report No.	
9. Performing Organization Name and Address Western Transportation Institute P.O. Box 174250 Bozeman, MT 59717-4250		10. Work Unit No. (TRAVIS)	
		11. Contract or Grant No. DTFH61-03-P-00398	
12. Sponsoring Agency Name and Address Federal Highway Administration Planning, Environment and Reality 1200 New Jersey Ave., SE Washington, DC 20590		13. Type of Report and Period Covered Final Report, August 2003 – February 2011	
		14. Sponsoring Agency Code HEPM-30	
15. Supplementary Notes COTR: Paul Garrett, FHWA-HQ. Advisory Panel Members: Mary Gray and Corrie Veenstra, FHWA-HQ; Brian Allen, FHWA-FLH; and Roger Surdahl, FHWA-CFLHD. This project was funded under the FHWA's Surface Transportation Environment and Planning Cooperative Research Program (STEP).			
16. Abstract This handbook provides numerous solutions to wildlife-vehicle interactions by offering effective and safe wildlife crossing examples. It initially describes the critter crossing problem and justifies the need to solve it. Project and program level considerations are identified for planning, placement and design of wildlife crossing structures. Key design and ecological criteria, construction and maintenance guidelines, and effective monitoring techniques are shown and described in this handbook's practical application examples called Hot Sheets.			
17. Key Words ANIMAL MOVEMENT BARRIERS, HABITAT CONNECTIVITY, HABITAT LOSS, ROAD ECOLOGY, WILDLIFE CROSSING, WILDLIFE MORTALITY, WILDLIFE-VEHICLE INTERACTION		18. Distribution Statement No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov .	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 224	22. Price

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	km
AREA				
in ²	square inches	645.2	Square millimeters	mm ²
ft ²	square feet	0.093	Square meters	m ²
yd ²	square yard	0.836	Square meters	m ²
ac	acres	0.405	Hectares	ha
mi ²	square miles	2.59	Square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	Milliliters	mL
gal	gallons	3.785	Liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	Newtons	N
lbf/in ²	poundforce per square inch	6.89	Kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	Hectares	2.47	Acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	Milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	Gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	Poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

TABLE OF CONTENTS

CHAPTER 1 – INTRODUCTION1
BACKGROUND1
JUSTIFICATION2
OBJECTIVES5
ORGANIZATION5
SUGGESTED READING6

CHAPTER 2 – WILDLIFE POPULATIONS AND ROAD CORRIDOR INTERSECTIONS...9
INTRODUCTION9
THE ECOLOGY OF ROAD CORRIDORS10
IMPACTS OF ROADS ON WILDLIFE POPULATIONS11
Change In Habitat11
Change In Wildlife Distribution14
ROAD-RELATED MORTALITY VS. BARRIER EFFECTS15
SUGGESTED READING18

CHAPTER 3 – IMPACT IDENTIFICATION, REMEDIATION, PLANNING AND
PLACEMENT.....21
INTRODUCTION21
STARTING OUT21
Rule of Thumb: Avoid, Mitigate or Compensate21
SCALED HABITAT CONNECTIVITY PLANNING23
Project-Level Approaches.....23
Systems-Level or Landscape-Level Approaches.....23
PLANNING RESOURCES27
Maps and Data27
GIS Layers32
How To Site Wildlife Crossings.....32
FIELD DATA.....32
Physical Data32
GIS-Based Movement Model35
No Data36
SUGGESTED READING38

CHAPTER 4 – DESIGNS, TOOLBOXES, GUIDELINES, AND PRACTICAL
APPLICATIONS41
INTRODUCTION41
FUNCTION OF WILDLIFE CROSSINGS AND ASSOCIATED MEASURES41
SPACING OF WILDLIFE CROSSINGS43
GUIDELINES FOR THE SELECTION OF WILDLIFE CROSSINGS47
Wildlife Crossing Design Types (Appendix C, Hot Sheets 1-11).....47
Wildlife Habitat Connectivity Potential52
Topography52
WILDLIFE SPECIES GROUPS AND CROSSING STRUCTURE CLASSIFICATION54

WILDLIFE CROSSING STRUCTURE HANDBOOK – TABLE OF CONTENTS

DESIGN AND DIMENSIONS	55
General Design Specifications For Wildlife Species.....	55
Specific Design of Wildlife Crossings and Adjacent Habitat.....	61
Hot Sheets 1-11 – Wildlife Crossing Prescriptions (Appendix C).....	65
Hot Sheets 12-14 – Fencing and Gate Guidelines (Appendix C).....	65
SUGGESTED READING	65
CHAPTER 5 – MONITORING TECHNIQUES, DATA INTERPRETATION, AND EVALUATIONS	67
CONSERVATION VALUE OF WILDLIFE CROSSINGS.....	67
AN APPROACH FOR MONITORING IMPACTS	70
MONITORING AND ASSESSMENT GUIDELINES.....	70
SETTING MONITORING AND PERFORMANCE TARGETS.....	71
Developing Performance Targets – Who Defines Them?	71
Reliably Detecting Change in Target Parameters.....	72
Developing Consensus-Based Performance Targets	72
FOCAL SPECIES.....	72
MONITORING TECHNIQUES.....	74
STUDY DESIGNS TO MEASURE PERFORMANCE	80
Inferential Strength	80
Types of Study Design and Resulting Inferential Strength	80
ADAPTIVE MANAGEMENT.....	81
SUGGESTED READING	82
APPENDIX A – GLOSSARY	85
APPENDIX B – COMMON AND SCIENTIFIC NAMES	93
APPENDIX C – HOT SHEETS	95
HOT SHEET 1: LANDSCAPE BRIDGE	95
HOT SHEET 2: WILDLIFE OVERPASS	103
HOT SHEET 3: MULTI-USE OVERPASS.....	109
HOT SHEET 4: CANOPY CROSSING	115
HOT SHEET 5: VIADUCT OR FLYOVER.....	119
HOT SHEET 6: LARGE MAMMAL UNDERPASS	125
HOT SHEET 7: MULTI-USE UNDERPASS.....	133
HOT SHEET 8: UNDERPASS WITH WATERFLOW	139
HOT SHEET 9: SMALL-TO-MEDIUM-SIZED MAMMAL UNDERPASS.....	147
HOT SHEET 10: MODIFIED CULVERT.....	155
HOT SHEET 11: AMPHIBIAN/REPTILE TUNNEL.....	159
HOT SHEET 12: FENCING – LARGE MAMMALS.....	169
HOT SHEET 13: FENCING – SMALL AND MEDIUM VERTEBRATES	181
HOT SHEET 14: GATES AND RAMPS.....	183
APPENDIX D – FRAMEWORK FOR MONITORING	187
APPENDIX E – MONITORING TECHNIQUES	193
APPENDIX F – OTHER HANDBOOKS AND GUIDELINES.....	209
APPENDIX G – PROFESSIONAL AND TECHNICAL JOURNALS.....	211

LIST OF FIGURES

Figure 1. Photo. Accidents with wildlife in rural and suburban areas are becoming a major safety concern for motorists and transportation agencies (credit: John Nordgren). 2

Figure 2. Photo. Wildlife crossings are becoming more common in highway expansion projects in North America. An example is the Greenway Landbridge on Interstate 75 in Marion County, Florida (Credit: Google Earth). 3

Figure 3. Photo. The highway system in the United States is used by more than 200 million vehicles and covers more than 6.2 million km (Credit: Tony Clevenger). 9

Figure 4. Schematic. Increasing road density fragments habitat into smaller patches and creates a disproportionate amount of edge habitat (from Iuell 2005). 11

Figure 5. Schematic. Barrier effects on populations. (A) A metapopulation consists of a network of local subpopulations that may vary in size and local dynamics but are linked to each other through dispersal. (B) Road construction causes a disturbance and loss of local populations within the network. In addition, infrastructure imposes a barrier to dispersal that can prevent recolonisation and isolate local subpopulations from the rest of the metapopulation. If important source populations are cut off from the remaining sink populations, the entire metapopulation may be at risk of extinction (from Iuell 2005)..... 12

Figure 6. Graph. Results of studies on the impact of traffic noise on breeding bird populations in The Netherlands. When the noise load exceeds a threshold of between 40 and 50 dBA, bird densities were found to drop significantly. The sensitivity to noise and the threshold is different between species and between forested and open habitats (from Reijnen, Veenbaas and Foppen 1995)..... 13

Figure 7. Photo. Mountain goats attracted to roadside vegetation along Highway 93 South in Kootenay National Park, British Columbia, Canada (Credit: Tony Clevenger)..... 13

Figure 8. Photo. Right-of-ways can vary considerably between different landscapes and parts of North America. Left: A two-lane highway in Jasper National Park. Dense vegetation of plants, shrubs and trees along roads provide potential nesting sites for birds and screen the road and its traffic from the surrounding landscape. Right: Interstate-65 in Kentucky consisting of a wide right-of-way with little native vegetation. (Credits: Tony Clevenger). 15

Figure 9. Graph. Conceptual model on the effect of traffic volume on the percentage of animals that successfully cross a road, are repelled by traffic noise and vehicle movement, or get killed as they attempt to cross. The conceptual model indicates that most collisions occur on intermediate roads (from Seiler 2003). 16

Figure 10. Photo. Lynx photographed using a wildlife overpass, as part of crossing structure monitoring along the Trans-Canada Highway in Banff National Park, Alberta. Long-term monitoring of the wildlife crossings in Banff has enabled the documentation of the crossings used by locally rare carnivores such as Lynx, and Wolverine (Credit: Tony Clevenger/WTI/Parks Canada). 18

Figure 11. Schematic. Representation of road construction and habitat (A) fragmentation (B) avoidance (C) mitigation by use of under/overpasses, and (D) compensation by creation of replacement habitat nearby (from Iuell et al. 2005). 22

Figure 12. Schematic. Location of alignment of highways with respect to habitat quality may have differential impacts on wildlife movements (dotted line). The impact of a highway alignment located on the periphery in sub-optimal habitat (yellow) would be expected to impact wildlife movements less than if the disturbance equally bisected optimal habitat (green). 22

WILDLIFE CROSSING STRUCTURES HANDBOOK – TABLE OF CONTENTS

Figure 13. Map. A project-scale analysis of connectivity emphasis areas (CEA) for the Interstate 90 Snoqualmie Pass East project area, Washington State. These are locations where wildlife crossing mitigations are proposed to be installed	24
Figure 14. Map. Statewide mapping of highways and fracture zones, blocks of wildlife habitat and connectivity linkage zones for Arizona (Source: Arizona Wildlife Linkages Work Group).	26
Figure 15. Map. Global position system (GPS) movement data from a male brown bear crossing a major four-lane highway and wildlife crossings (blue circle) in Croatia (Source: D. Huber, Zagreb University).	33
Figure 16. Photo. (A) Use of track beds is one method for obtaining information on wildlife movement across roads and key crossing locations prior to installation of wildlife crossing structures. (B) Raking of track beds along US 93 in Montana to collect pre-mitigation information on wildlife movements in the highway corridor (Credits: M. Huijser).	34
Figure 17. Map. DNA sampling grid in Banff National Park. Hair snag sites and rub tree sites were used to collect population genetic data on individuals in the population and from bears using the wildlife crossings on the Trans-Canada Highway (Source: WTI/Parks Canada)...	35
Figure 18. Chart. Types of measures used to reduce the impacts of roads on wildlife (adapted from Iuell 2005).	42
Figure 19. Photo. Benavente, Spain. Highly fragmented landscape (high contrast; adapted from Google Earth).	44
Figure 20. Photo. Hwy 101, Redwood highway, California. Low contrast landscape with low level of habitat fragmentation (adapted from Google Earth).	45
Figure 21. Chart. Criteria for selecting general wildlife crossing type where roads bisect habitats of high conservation value.	49
Figure 22. Chart. Criteria for selecting general wildlife crossing type where roads bisect habitats of moderate conservation value.	50
Figure 23. Chart. Criteria for selecting general wildlife crossing type where roads bisect habitats of low conservation value.	51
Figure 24. Schematic. Four general types of topography where wildlife crossings maybe constructed on roadways (Credit: Tony Clevenger).	53
Figure 25. Schematic. Length and width measurements of wildlife overpass (Credit: Tony Clevenger).	59
Figure 26. Photo. Width and height measurements of wildlife underpass structure (Credit: Marcel Huijser/WTI).	59
Figure 27. Photo. Most wildlife overpasses or landscape bridges are less than 70-80 m long; however, the one shown above near Hilversum, The Netherlands, is 800 m long and spans two roads and a railroad. (Credit: Goois Natuurreservaat, The Netherlands/Photo: W. Metz).	60
Figure 28. Photo. Crossing structures are site-specific movement corridors that link wildlife habitat separated by pavement and high-speed vehicles (Credit: Jeff Stetz).	68
Figure 29. Photo. Landscape bridge (Credit: Anonymous).	95
Figure 30. Photo. Closure signage (Credit: Tony Clevenger).	96
Figure 31. Photo. Brush piles on wildlife overpass (Credit: Tony Clevenger).	99
Figure 32. Photo. Constructed amphibian habitat on edge of wildlife overpass (Credit: Tony Clevenger).	101

WILDLIFE CROSSING STRUCTURES HANDBOOK – TABLE OF CONTENTS

Figure 33. Photo. Recently completed but unlandscaped wildlife overpass (Credit: Tony Clevenger).....	103
Figure 34. Photo. Berm on wildlife overpass (Credit: Tony Clevenger).....	104
Figure 35. Schematic. (A) Parabolic-shaped design overpass (B) Straight-edged design.....	105
Figure 36. Photo. Human use lane and vegetated strip on multi-use overpass (Credit: Marcel Huijser).....	110
Figure 37. Photo. Canopy crossing installed in permanent signage fixture (Credit: Tony Clevenger).....	116
Figure 38. Photo. Ropes extending out from canopy crossing to forest canopy (Credit: Tony Clevenger).....	116
Figure 39. Photo. Viaduct as wildlife underpass (Credit: Ministère des Transports du Québec).	119
Figure 40. Photo. Wide span viaduct designed to conserve floodplain (Credit: Tony Clevenger).	120
Figure 41. Photo. Viaduct with retention of riparian vegetation (Credit: Tony Clevenger).....	121
Figure 42. Photo. "Stepping stone" ponds on wildlife overpass used to assist amphibian movement (Credit: Tony Clevenger).	123
Figure 43. Photo. Open span wildlife underpass (Credit: Tony Clevenger).....	126
Figure 44. Photo. Brush and root wads placed along underpass wall to provide cover for mammals (Credit: Nancy Newhouse).	127
Figure 45. Photo. Multi-use underpass in The Netherlands retrofitted for human use and wildlife passage (Credit: Marcel Huijser).	133
Figure 46. Photo. Wildlife underpass designed to accommodate waterflow (Credit: Tony Clevenger).	139
Figure 47. Photo. Mechanically stabilized earth (MSE) wall serving as wildlife exclusion "fence" (Credit: Tony Clevenger).	142
Figure 48. Photo. Pipes placed in culverts to provide cover for small mammal movement (Credit: Tony Clevenger).	144
Figure 49. Photo. Small- to medium-sized mammal underpass (Credit: Tony Clevenger).....	147
Figure 50. Photo. Continuous wildlife underpass on divided highway (Credit: Tony Clevenger).	149
Figure 51. Photo. American marten using a drainage culvert to cross the Trans-Canada Highway, Banff National Park, Alberta (Credit: Tony Clevenger).	151
Figure 52. Photo. Badger tunnel in The Netherlands (Credit: Tony Clevenger).....	151
Figure 53. Schematic. Technical design plan for artificial kit fox den in culvert (Credit: US Fish and Wildlife Service).	153
Figure 54. Schematic. Modified culvert (Reprinted with permission from Kruidering et al. 2005).....	155
Figure 55. Photo. Construction and placement of amphibian tunnel in Waterton National Park, Alberta (Credit: Parks Canada).	159
Figure 56. Photo. Drift fence for amphibians and reptiles (Credit: Tony Clevenger).....	160
Figure 57. Photo. Grated slots on amphibian tunnels allows light and conservers ambient temperatures and humidity (Credit: Anonymous).....	161
Figure 58. Photo. Flooding in front of tunnel due to improper drainage design (Credit: Tony Clevenger).	163

WILDLIFE CROSSING STRUCTURES HANDBOOK – TABLE OF CONTENTS

Figure 59. Photo. Construction of amphibian ramp to replace curb and allow cross-road movement of long-toed salamanders (Credit: Parks Canada)..... 164

Figure 60. Photo. Barrier or drift fence for amphibians and reptiles (Credit: Tony Clevenger). 165

Figure 61. Photo. Drift fence and collection buckets (Credit: Tony Clevenger)..... 166

Figure 62. Photo. Wildlife exclusion fencing and culvert design wildlife underpass (Credit: Tony Clevenger)..... 169

Figure 63. Photo. Cattle guard (Texas gate) in road (Credit: Tony Clevenger). 171

Figure 64. Photo. Step gate with spring-loaded door situated at trailhead in Banff National Park, Alberta (Credit: Tony Clevenger). 172

Figure 65. Photo. Wildlife exclusion fence with buried apron (Credit: Tony Clevenger). 175

Figure 66. Photo. Concrete base of swing gate to prevent animal digging under wildlife fence (Credit: Tony Clevenger). 175

Figure 67. Photo. High tensile cable designed to break fall of trees onto fence material (Credit: Tony Clevenger)..... 176

Figure 68. Photo. Warning signage at end of wildlife exclusion fence (Credit: Tony Clevenger). 177

Figure 69. Photo. Boulder field at end of wildlife fence (Credit: Tony Clevenger)..... 179

Figure 70. Photo. Small and medium-sized mammal fence material spliced to large mammal fence material (Credit: Nancy Newhouse). 181

Figure 71. Photo. Escape ramp (jump-out) for wildlife trapped inside highway right-of-way (Credit: Tony Clevenger). 183

Figure 72. Photo. Single swing gate in wildlife exclusion fence (Credit: Tony Clevenger). ... 184

Figure 73. Photo. Wildlife escape ramp (jump-out; Credit: Tony Clevenger). 185

Figure 74. Photo. Hinged door for escape of medium-sized mammals (Credit: Tony Clevenger). 186

Figure 75. Photo. Remote digital infrared-operated camera (Credit: Tony Clevenger/WTI). . 193

Figure 76. Photo. Raking of track bed in culvert Banff National Park, Alberta (Credit: Tony Clevenger/WTI). 195

Figure 77. Photo. Sooted track plate with tracks of small and medium-sized mammals (Credit: Robert Long/WTI)..... 197

Figure 78. Schematic. Diagram of hair-snagging system at a wildlife underpass used in DNA-based research of population-level benefits of crossing structures (Source: Tony Clevenger/WTI). 199

Figure 79. Photo. Grizzly bear passing through hair-snagging device at wildlife overpass in Banff National Park, Alberta (Credit: Tony Clevenger/WTI). 200

Figure 80. Photo. Digital barcode tag for frogs (Source: Steve Wagner/CWU). 201

Figure 81. Photo. Scat-detection dog working to locate scat (Credit: Robert Long/WTI)..... 203

Figure 82. Photo. Roadkill Observation Collection System (ROCS) (Credit: WTI)..... 205

LIST OF TABLES

Table 1. Data layers and maps for planning wildlife connectivity and crossing mitigation..... 29

Table 2. Average spacing interval per mile between wildlife crossings designed for large mammals at existing and planned transportation projects. 47

Table 3. General guidelines for minimum and recommended dimensions of wildlife overpass designs..... 56

Table 4. General guidelines for minimum and recommended dimensions of wildlife underpass designs..... 57

Table 5. Suitability of wildlife crossing design types from Appendix C, Hot Sheets 1-11 for distinct wildlife species and taxa..... 62

Table 6. Levels of conservation value for wildlife crossing systems as measured by ecosystem function achieved, level of biological organization targeted, type of connectivity potential, and cost and duration of research required to evaluate status. 69

Table 7. Guide to selecting focal species based on monitoring criteria and ecosystem context. 73

Table 8. Summary of available monitoring methods, the appropriate time to employ them (pre- or post-construction), potential target species, and cost estimates for conducting wildlife monitoring. See Appendix E for detailed description of each monitoring method (From Clevenger et al. 2008). 75

