

Monitoring strategy for wildlife crossings and fencing on Highway 69, north of Highway 637

Final Report

GWP 5379-02-00

August 2009

Prepared for:
The Ministry of Transportation, Northeastern region

Prepared by:
Eco-Kare International



Report Citation:

Eco-Kare International. 2009. Monitoring strategy for wildlife crossings and fencing on Highway 69, north of Highway 637. Final Report submitted to the Ministry of Transportation, Northeastern Division.

Photo Caption (cover): Aerial image of construction of 60 m wide overpass, June 2009, Trans-Canada Highway, Lake Louise, Alberta.

Photo Credit (cover): Dale Wolfe, Eco-Kare International

Table of Contents

I. Background & Information.....	1
A. Study Area.....	2
B. Summary of Phase I.....	3
a) Major Points.....	3
i. Wildlife Crossing Monitoring.....	3
ii. Fence Monitoring.....	4
b) Performance Measures Identified.....	4
i. Wildlife Crossing Monitoring.....	4
ii. Fence Monitoring.....	4
c) Desired criteria for the Preferred Monitoring Strategy.....	4
i. Wildlife Crossing Monitoring.....	4
ii. Fence Monitoring.....	5
II. Methods for Phase II.....	5
A. Wildlife Crossing Monitoring.....	5
a) System Components Identified.....	5
b) Economic Models.....	6
b) Qualitative Synthesis.....	6
III. Results for Phase II.....	7
A. Wildlife Crossing Monitoring.....	7
a) Economic Models.....	7
b) Qualitative Synthesis.....	7
IV. Discussions.....	11
A. Wildlife Crossing Monitoring.....	11
a) Economic Models.....	11
b) Qualitative Synthesis.....	11
V. Recommendations.....	12
A. Wildlife Crossing Monitoring.....	12
B. Fence Monitoring Study Design.....	13
VI. References.....	16

Appendices

Appendix A – Projects using Reconyx cameras

Appendix B – Example of camera (digital or video) set-up

Appendix C – Relevant websites

Appendix D – Email Communication

Appendix E – Economic Model

I. Background Information

The design and construction of mitigation measures, wildlife crossing structures and fencing, has been incorporated into the construction contracts to four-lane Highway 69 from just south of Highway 637 at Lovering Lake Road to 8.7 km north of Highway 637 under G.W.P. # 5379-02-00. These include a wildlife overpass, a joint-use culvert, smaller 'turtle' culverts, oversized bridges at Lovering Creek and Lovering Lake Road, and associated fencing.

The wildlife overpass (30 m wide), joint-use culvert (5m x 5m), and associated 2.8 meter high fencing, are the first of their kind to be built in the province of Ontario, and their objectives are to reduce wildlife road mortality (namely elk and moose), while ensuring connectivity for wildlife across the new road. Wildlife-vehicle collisions (WVCs) have become a direct consequence of increased road-building as a result of increasing traffic volumes. Crossing structures with fencing has proved effective to reduce the number of collisions creating safer roads for both motorists and wildlife (Clevenger et al. 2001, Parker et al. 2008).

The objective for this study is to devise a long-term monitoring strategy that will measure the effectiveness of the two larger crossing structures, the overpass and joint-use culvert (underpass), and fencing. The strategy will be composed of two components:

- devising a system that will measure the multi-species animal passage rate at the crossing structures
- measuring the number of wildlife-vehicle collisions to rigorously determine if the fencing is effective

Eco-Kare International was retained by AECOM Canada to provide expertise on a suitable monitoring strategy for wildlife crossings and fencing on Highway 69, north of Highway 637.

A. Study Area

The project study area involves the four-laning of approximately 9.4 km of Highway 69 from just south of Highway 637 northerly to Trout Lake Road (Figure 1). Figure 1 shows the new highway and the approximate locations of the overpass, underpass, smaller culverts and the end of fence.

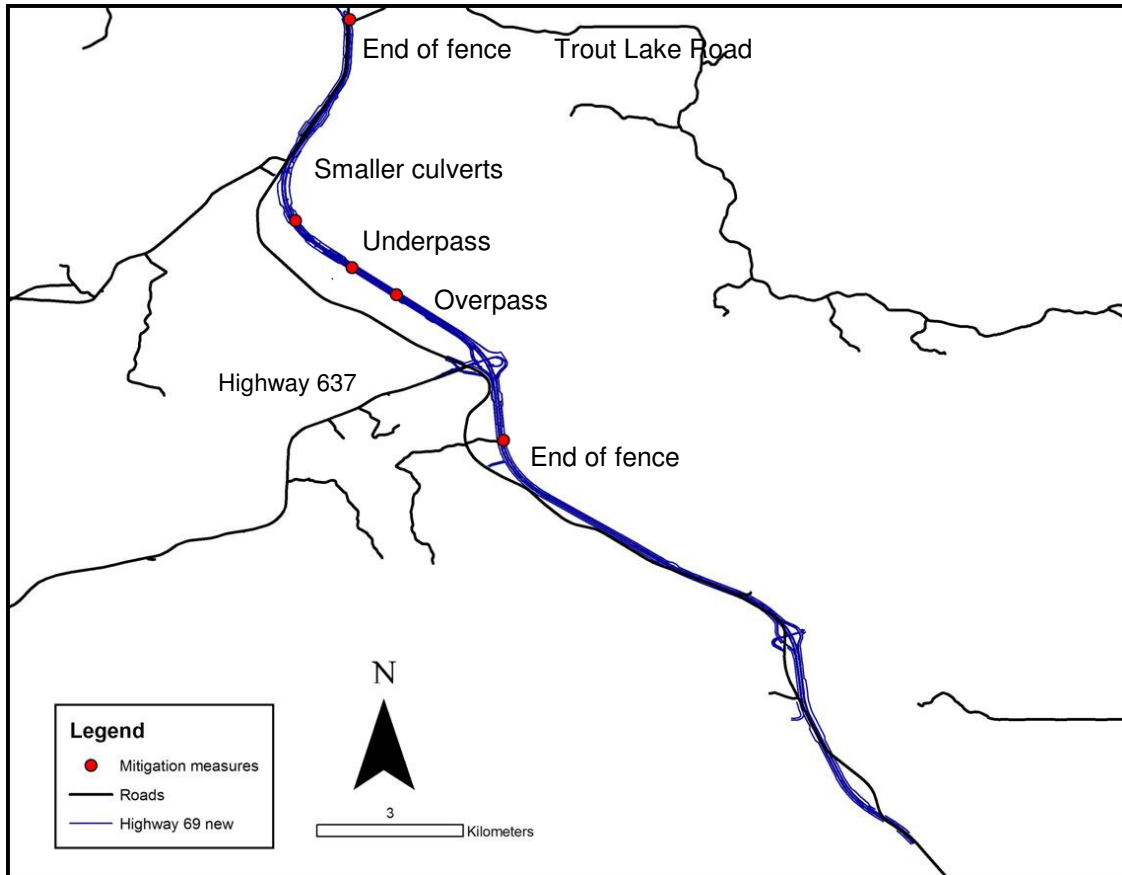


Figure 1. New Highway 69 with the approximate locations of the overpass, underpass, smaller culverts, and the end of fence on the north and south side of the study area.

B. Summary of Phase I

Phase I of this study entailed a compilation of pertinent literature, and consultant expertise into a PowerPoint presentation. A meeting was held on February 11th, 2009 at the Ministry of Natural Resources office in Sudbury to discuss and review possible types of monitoring strategies for the mitigation measures placed on Highway 69. The attendees consisted of two Ministry of Transportation representatives (Heather Garbutt, and Josee Vallee), two representatives from the Sudbury Elk Restoration Committee (Ivan Filion and Joseph Hamr), one representative from the Ministry of Natural Resources (Mike Hall), and two consultants from Eco-Kare and AECOM (Kari Gunson and Brian Ruck respectively).

B. Ruck gave a short background address of the overall project south of Trout Lake Road and noted that special features were being incorporated into the construction contracts to accommodate wildlife passage through the new highway. These include a wildlife overpass, an underpass, ‘turtle’ culverts, oversized bridges at Lovering Creek and Lovering Lake Road, and associated fencing. K. Gunson gave a 2 hour interactive PowerPoint presentation introducing the review of ideas and strategies used elsewhere to monitor crossing structures and its associated fencing. Throughout the meeting, feedback and discussion was generated to refine the objectives for Phase II (final report compilation) of the study. The following main points were presented during the meeting:

a) Major Points

i) Wildlife Crossing Monitoring

- The overpass and underpass should have identical monitoring strategies to allow comparison for passage rate at the structures.
- Remote triggered camera systems were proven to be more cost-effective and rigorous than sand-pad tracking data for determining elk and deer passage rates at crossing structures in Banff National Park (Ford et al. in press).
- Digital cameras with the correct settings can adequately assess behaviour and passage of animals at the crossing structures.
- 2 to 3 cameras are needed at each structure to assess traffic volume, and through passages.
- Several motion activated camera designs are available, including a video camera system used by the Sudbury Elk Restoration Committee.
- The majority of large wildlife monitoring projects in western North America are using Reconyx (www.reconyx.com) digital camera systems, e.g. Banff National Park, Montana, Idaho, Wyoming. See attached **Appendix A** for an account of these projects.
- Wireless transmission of data may be an option for the overpass and underpass if there is line of sight (SERC, personal communication).
- An electrical or solar power source may be options for the overpass and underpass.
- The monitoring strategy should be reliable, and functional for the majority of the year, throughout the day.

- It was agreed that the total life cycle cost of monitoring needs to be considered, not just the up front start-up costs, since it is possible that the data gathering costs can exceed the installation costs.
- Additional technical advice on the monitoring system may be required at a later date depending on the selected monitoring system.

ii) Fence Monitoring

- The fence effectiveness monitoring should be considered as part of the overall monitoring project.
- Spatial error ranging from (0 m to 6500 m) for wildlife-vehicle collision location data can be avoided with the use of a geographic positioning system (GPS) by highway maintenance contractors or a research monitoring team.
- Because there isn't any pre-mitigation road mortality data on the new road and the data that exists on the old road isn't species-specific and the spatial accuracy is unknown, it was recommended to collect accurate, species-specific data on the new road (experimental) in addition to a road segment (control) with similar habitat and landscape characteristics.

b) Performance Measures Identified

i) Wildlife Crossing Monitoring

- Multispecies usage
- Percent passage rate
- Behaviour assessment
- Passage rate as a function of traffic volume, weather, and crossing structure type

ii) Fence Monitoring

- Road mortality reduction
- Spatial (control vs. experimental) and temporal (pre vs. post) comparisons
- Road mortality as a function of species, and spatial location

c) Desired Criteria for the Preferred Monitoring Strategy

i) Wildlife Crossing Monitoring

- Video or Digital
- Cost-effective
- Logistics for data collection
- Technical installation-lighting, remote-triggers, power, etc.
- User-friendly
- Human presence
- Operate at all ambient climatic temperatures
- Reputable
- Rigorous-ability to publish results

ii) Fence Monitoring

- Cost effective
- Labour hours
- Technical requirements
- Spatial accuracy
- Rigorous-ability to publish results

II. Methods for Phase II

From Phase I it was decided that the performance functions and the criteria identified will be assessed for various systems to assist the Ministry with the selection of a preferred monitoring system on the overpass and underpass. We therefore created hypothetical systems and compared the advantages and disadvantages of each system as per each of the desired criteria.

*A. Wildlife Crossing Monitoring**a) System Components Identified*

We simulated several combinations of possible camera systems to monitor wildlife passage on the crossing structures, based on three categories: Camera Type, Power Source, and Data Transmission (Table 1). We did not include track pad monitoring as a possible monitoring scenario because Ford et al. (in press) showed that animal detection by camera was superior for most wildlife (not including grizzly bears and coyotes), at crossing structures in Banff National Park. It is important to note that in addition to identified major components, there are other minor components that need to be taken into consideration. These include the infra-red remote triggers, lighting for night shots, and power regulators and transformers.

For wildlife monitoring at crossing structures the digital camera type (e.g. Reconyx www.reconyx.com) is able to run effectively for prolonged periods (i.e. up to 1 month) using eight 'double A' batteries (Table 1). The video camera type require more power to collect data, therefore to limit human visitation for battery replacement, alternative power sources, wind/battery, solar/battery and electrical were used to run video data output (Table 1).

Manual data capture would require a field technician to visit the structure and download the data, and or replace the memory card. Hard-wire transmission used a telephone communications line installed from Bell and the estimated price was dependent on the presence of electricity poles. Wireless was assumed to be possible if there is a line of site to the receiver (Ivan Fillion, personal communication). An electrical power source would require the installation of wood poles and an electricity cable.

Table 1: An outline of the six camera systems investigated for this study. Systems vary according to camera type, power source, and data transmission.

Camera Type	Power Source	Data transmission	Abbreviation
Digital	Battery	Manual	DBM
Video	Wind/Battery	Manual	VWM
Video	Solar/Battery	Manual	VSM
Video	Electrical	Manual	VEM
Video	Electrical	Hard-wire	VEH
Video	Electrical	Wireless	VEW

b) Economic Model

Cost was considered to be an important criteria in devising a monitoring strategy, therefore we adapted an economic model by Ford et al. (in press) to describe the start-up and operating costs for the six different system scenarios in Table 1 for each year up to a maximum of 10 years. We used Excel to build all models, and the spreadsheet was designed so that if the variable cells in the spreadsheet (colour-coded yellow) were manipulated the spreadsheet would automatically update itself (see Appendix E).

Costs were treated in 2 separate categories: start-up costs and operating costs. Start-up costs included equipment, software, and installation expenses. Start-up costs for equipment were approximated from the current market value, from other case studies in wildlife monitoring, and from manufacturer quotes available on the internet. It was assumed that there would be 3 cameras for each of the 2 structures in order to assess passage rate (see Appendix B for camera set-up). The electrical power source and hard-wire transmission costs were determined from quotes from AECOM engineers and Bell communications (Josee Vallee & Brian Ruck, personal communication). The technician costs for installation were estimated at \$100.00/hour for the DBM system and \$200.00/hour for all other systems, herein referred to as Hi-Tech systems. These costs were based on the assumption that a system that requires an alternate power source to batteries such as renewable or electrical would require a specialized engineering technician.

Operating costs are only calculated for data collection from the crossing structures and do not include in-house data management and synthesis costs. Operating costs included technician wages (\$100.00/hour), power supply costs, and vehicle expenses. Technician costs assume a biologist consultant wage for data collection. Vehicle costs are intended to encompass fuel, maintenance and insurance. The cost of surveying the structures per visit was based on a circuit distance of 100 km and a circuit time of 8 hours. The monitoring interval for the DBM, VSM, VWM and VEM systems were 1 visit per month, and the VEH and VEW were 1 visit every 3 months. It is important to note that the circuit time and circuit distance will all vary according to where the monitoring crew will be traveling from.

c) Qualitative Synthesis

For this synthesis we tabulated the advantages and disadvantages of using each system as per the desired criteria defined in Phase I. The desired criteria considered footage type (video vs. digital), cost, human presence, logistics, operational requirements, supportive literature, and

innovative capabilities (Table 3). We then selected the best system that would meet the desired criteria.

III. Results for Phase II

A. Wildlife Crossing Monitoring

a) Economic Models

Table 2 displays the start-up costs, annual operating costs, and the total costs

$$\text{Equation 1} \quad \text{Total costs} = [\text{start up} + (\text{year} * \text{annual operating cost})]$$

for 1, 3, 5, 8, and 10 years derived from the economic model (Excel spreadsheet, supplementary material). The Digital-Battery-Manual had the lowest start-up costs (~ \$16,000) and was twelve times less expensive than the Video-Electrical-Hard-wire system at ~\$184,000. Total costs for the DBM system over the ten year period were the lowest at ~ \$119,000. The Hi-Tech electrical systems (VEM, VEH, & VEW) had the highest total costs over the ten year period (~250,000) and the solar and wind Hi-Tech systems were moderately expensive (~150,000).

We used the cost ratio between the Video-Electrical-Hard-wire system and the Digital-Battery-Manual system to show the relative cost difference between a battery system and a Hi-Tech system (Table 2). The start-up costs for the Video-Electrical-Hard-wire system is twelve times more expensive than the Digital-Battery-Manual system which is not off-set by the cheaper annual operating costs of the system over a 10 year monitoring period. At year 1, the total life-cycle costs [(Start-up + (Year*Annual Operating Cost))] is 7.3 x higher than the DBM system; however this cost differential decreases to 2.0 times at year 10.

Table 2. A summary of the costs generated from the economic model for the 6 camera system types. All amounts are rounded to the nearest whole number.

Costs	DBM (\$)	VSM (\$)	VWM (\$)	VEM (\$)	VEH (\$)	VEW (\$)	Ratio- VEH/DBM	
Start-up costs	16,000	52,000	51,000	124,000	184,000	204,000	12	
Annual Operating Costs	10,000	10,000	10,000	12,000	6,000	6,000	0.6	
Total	1	26,000	62,000	61,000	136,000	190,000	210,000	7.3
Life- Cycle Costs (year)	3	47,000	83,000	82,000	159,000	202,000	222,000	4.3
	5	67,000	104,000	103,000	182,000	213,000	233,000	3.2
	8	98,000	134,000	133,000	216,000	231,000	251,000	2.4
	10	119,000	155,000	154,000	239,000	242,000	262,000	2.0

b) Qualitative Synthesis

Table 3 displays the results of the qualitative evaluation of the advantages and disadvantages of the desired criteria for each monitoring system type. The Digital-Battery-Manual system was selected as the best system to meet six of the desired criteria, while the VSM, VWM, and VEM

were only selected to best meet two of the criteria, and the VEH and VEW systems were selected to best meet four of the criteria.

The DBM system scored high as a highly operational, cost-effective, user-friendly and logistically favourable system. It is also supported by other projects and there exists the most published peer-review papers documenting its efficiency. The other systems used video footage, and were innovative. The VEH and VEW systems limited human presence at the structures. An explanation of the defined criteria and the qualitative evaluations is explained in the Discussions.

Table 3. An outline of the comparative analysis displaying how each system meets the desired criteria, with a final recommendation for the system that best meets the criteria. Contents of the table are based on consultant experience, expert opinion and a literature review.

Criteria	Digital-Battery-Manual (DBM)	Video-Solar/Battery-Manual (VSM)	Video-Wind/Battery-Manual (VWM)	Video-Electrical-Manual (VEM)	Video-Electrical-Hardwire (VEH)	Video-Electrical-Wireless (VEW)	Recommended system
1) Video footage or digital?	Digital	Video	Video	Video	Video	Video	Hi-Tech System
2) Start-up costs	Low	Medium	Medium	High	High	High	DBM
3) Total life-cycle costs [(annual operating* Year) + start-up costs]	Low	Medium	Medium	High	High	High	DBM
4) Human presence (< year 1) as function of the monitoring interval (MI)	MI=2 weeks to 1 month, require trial and error to determine power supply and data storage as a function of wildlife use.	MI=2 weeks to 1 month, require trial and error to determine power supply and data storage as a function of temperature and wildlife use	MI=2 weeks to 1 month, require trial and error to determine power supply and data storage as a function of temperature and wildlife use	MI=1 month, require trial and error to determine data storage as a function of wildlife use e.g. 10 animal crossings/day with 30 sec. footage on 2 hour tape	MI=1-2 months, require trial and error as a function of malfunction and servicing	MI =1-2 months, require trial and error as a function of malfunction and servicing	Difficult to ascertain
5) Human presence (> year 1) as function of the monitoring interval (MI)	MI= 1 month	MI=1-2 months	MI=1-2 months	MI=1-2 months	MI=3 months	MI=3 months	VEH & VEW
6) Integrate crossing structure monitoring interval with fence monitoring interval	Good	Moderate	Moderate	Poor	Poor	Poor	DBM
7) Operational in all ambient climate conditions	Good (tested to operate between +40 C and -40 C)	Unknown	Unknown	Good (may require additional temperature control	Good (may require additional	Good (may require additional	DBM, VEM, VEH & VEW

				device	temperature control device	temperature control device	
8) Supportive literature for rigorous data collection (peer-reviewed published papers and reports)	4 peer reviewed papers: Ford et al. (in press), Mata et al. (2005), Braden et al. (2008), & Olsson et al. (2008), 4 known projects in western Ontario (Appendix A)	Kleist et al. (2007); Dodd et al. (2007)	None	4 peer reviewed papers: Dodd et al. (2007), D'angelo et al. (2006), *Mathesen & Madsen (2000), *Fehlburg (1994)	None	None	DBM
9) User-friendly	Yes	No	No	No	No	No	DBM
10) Innovative technology-not used in wildlife monitoring before	Poor	Good	Good	Poor	Good	Good	VSM, VWM, VEH, VEW

*These studies have stated that they used video surveillance however the power source is unknown.

IV. Discussions

A. Wildlife Crossing Monitoring

a) Economic Model

The economic model is an excellent tool to provide a relative comparison between different system types, and to assist in decision-analysis for assessing cost when selecting an appropriate monitoring system. However the set-up and operating costs were estimated and should not be used to determine the actual monitoring start-up and operating costs. It is difficult to determine exact start-up and annual operating costs without knowing several factors such as animal activity, and logistical constraints for the monitoring personnel. For example, to determine circuit costs for monitoring we used an estimated monitoring interval for a solar/wind powered system at 1 month. However the solar/wind powered system uses video footage which requires more storage space than digital data which may be a limiting factor requiring increased site visits, especially during times of heavy animal movements across the structures. In addition, if the system is monitored by a field technician closer than 100 km from the study site this would reduce the circuit costs (travel costs, and labour hours). All numbers in the Excel spreadsheet can be manipulated to depict specific monitoring scenarios.

b) Qualitative Synthesis

An important criterion (Criteria 1, Table 3) is to select whether video or digital footage is desired at the crossing structures, both of which are capable of obtaining the data needed to rigorously measure wildlife passage use at the crossings structures. An advantage of video film is the increased ability to evaluate wildlife behaviour as the animals use the structure. Another advantage is the public may be more receptive to moving video film rather than still multiple images. The trade-off is video footage is more Hi-Tech because it requires more data storage, and power and therefore more technical expertise to run and set-up the system. Digital camera systems are more user-friendly and allow wildlife behaviour to be assessed with rapid fire settings that allow several pictures (up to 5 frames per second) to be taken per trigger (see Banff Wildlife Crossing Poster, Parks Canada).

Human presence (Criteria 4, Table 3) was divided into < 1 year and > 1 year because all systems will require a trial and error period throughout each season in year 1. This may require more visitation than expected and human presence is difficult to ascertain before construction. After year 1, a combination of electrical-hard-wire, or wireless will shorten the monitoring interval that is dependent on malfunction and maintenance (Criteria 5, Table 3). If monitoring of the crossing structures is integrated with fence monitoring, i.e. the same personnel collecting data for all highway mitigation than a shorter monitoring interval may be required (Criteria 6, Table 3).

The DBM system has been proven to work effectively in extreme hot (+ 40 ° C) and cold (- 40 ° C) temperatures (see www.reconyx.com). The other systems using renewable power or electricity would require the purchase of weather proofing equipment and trial and error to determine their operational capacities in extreme weather events (see Appendix D, email communication).

The results for Criteria 8, Table 3 were obtained from a 'Web of Science' database search using 'road' 'wildlife' 'video' and 'camera' as the keywords along with a summary of known progress reports from other projects in North America. There were a total of 9 papers found, 4 papers used the Digital-Battery-Manual system, 2 used Video-Electrical-Manual, and 2 used a solar-powered video camera system. Two of the papers used video surveillance however the power source was unknown. This additional information can assist in system installation and ensure rigorous data collection. Appendix A has a compilation of known projects in western N. America using a Digital-Battery-Manual system (specifically Reconyx systems, www.Reconyx.com).

The DBM system was deemed user-friendly because all the components were in one unit and could be easily serviced and managed by a field technician with minimal training (e.g. 1 day), (see Criteria 9, Table 3). The other four systems would require a specialized service consultant to repair and maintain the system and requires separate lighting, remote triggers, and power components.

The systems were graded as having state-of-the art and innovative technology according to whether they had been documented previously for wildlife crossing structure monitoring (Criteria 10, Table 3). The use of solar power systems have been used by other studies (see Kleist et al. 2007, Dodd et al. 2007), however wind energy has not been used. In addition, as far as we know the use of a wireless or hard-wire capability for transmission has not been used previously for wildlife monitoring on crossing structures.

V. Recommendations

A. Wildlife Crossing Monitoring

In light of the completed research for this study we recommend the Digital-Camera-Manual system to obtain reliable, consistent, and user-friendly, 24 hour wildlife surveillance. With the use of 3-4 synchronized cameras with rapid fire settings (Appendix B), passage rates and behaviour can be evaluated in order to obtain rigorous results.

If the Ministry requires video footage that will evaluate more detailed behaviour and provide excellent public relations media we recommend the use of a video system (e.g. Margalida et al. 2006 & <http://www.seemorewildlife.com/remotedvr.php>) as supplementary, e.g. during the summer months. Of special note is a study by Kleist et al. (2007), which used 2-3 12-V deep-cycle marine batteries and solar panels to power 2 digital video recording systems on an overpass in North Carolina. The system ran for 4-7 days with the batteries, and continuously with two 123-W solar panels. Another study (Dodd et al. 2007) in Arizona used a combination of solar and electrical power to power 4 cameras, 5 triggers, and 8 illuminator systems at each of 2 structures.

We recommend renewable powered systems with caution or as supplementary at this point, because these systems may only be reliable and operational with favourable ambient weather conditions (see Appendix D, personal communication, Jeff Gagnon). Previous studies have used solar panels in climates with more sun relative to northern Ontario. Adequate testing, a review of literature, and or additional expertise is required to determine if the current solar and wind technology is adequate to power a 3-4 camera system, remote triggers, and illuminators

throughout the year. This expertise will be retained by AECOM (Brain Ruck, personal communication, meeting North Bay, May 6th, 2009).

The electrical manual or hard-wire system is not recommended since the ten-year life-cycle costs are considerably higher (> 2 times) than the digital-battery or video-solar systems to warrant installation of electrical or hard-wire transmission. A previous study that used electrical power sources to run their wildlife surveillance system had buried cable with a power sources 200 – 300 m from the system (Dodd et al. 2007).

Security is a major issue for all cameras systems in order to prevent theft of cameras and their equipment. In Utah, the threat of vandalism and theft of cameras and their components was mitigated by using locked utility boxes, bolted to metal stakes which were driven into the ground 2 to 3 feet (Patty Kramer, Utah State University, personal communication).

B. Fence Monitoring Study Design

Road-kill data collection is required to rigorously measure the effectiveness of the ~ 10 km of fencing installed on Highway 69. Spatial error of the data collected, and the spatial and temporal extents for data capture need to be addressed for rigorous road-kill data collection. There are three options for wildlife-vehicle collision data collection that have varying spatial accuracy (see Gunson et al. 2009):

- 1) Use a geographic Information System (GPS) for recording the location of wildlife mortalities {10-100 m}
- 2) Measure wildlife mortalities to the closest km on the road {401 m (SD, range) (219 m, 7 - 794 m)}.
- 3) Measure wildlife mortalities to the closest landmark {516 m (SD, range) (808 m, 0 - 6500 m)}.

We recommend collecting the road-kill data using a GPS unit because it limits human bias and also has the least spatial error maximizing its use for spatial analysis. Obtaining all the locations for animals killed on the roads will entail driving surveys completed by field technicians or maintenance contractors during routine road maintenance checks. Contractors would need to take note of the species, date, time, and GPS coordinates for each road-kill in a notebook or database. It is important that the data is received by the personnel responsible for data analysis in a consistent and orderly manner, e.g. telephone or email. This method will require consistent training and data check-ups (e.g. 2 weeks to 1 month) in order to be effective.

Rigorous data analysis to measure fence effectiveness through road-kill counts entails either pre and post data comparison (temporal), or control versus experimental comparison (spatial). In light of the absence of pre-mitigation road-kill data on the new road and the lack of spatial accuracy (> 100 m) and species specificity for the road-kill data on the old road, it is recommended to collect accurate, species-specific data on the new road (experimental) in addition to a near by road segment (~ 9 km) to behave as a control. The two segments (control

and experimental) should have similar habitat topography, wildlife species composition, traffic volumes, and road width to complete a rigorous measure of fence effectiveness.

Clevenger (2001), has shown that fence ends can become road mortality hotspots for wildlife, therefore it is also important to include road-kill surveying at least 500 m beyond both fence ends. In addition, it would be worthwhile to determine the behaviour of animals at the fence-ends. Snow-tracking techniques, and or video/digital camera surveillance can evaluate behaviour by determining if the animal travels around the fence into the highway right-of-way, approaches the end of fence and continues down the highway, the animal crosses the road, or the animal turns around and goes back in the same direction it came.

VI. References

- Braden, A.W., Lopez, R.R., Roberts, C.W., Silvy, N.J., Owen, C.B., Frank, P.A. 2008. Florida key deer, *Odocoileus virginianus clavium*, underpass use and movements along a highway corridor. *Wildlife Biology*. 14:155-163.
- Clevenger, A.P., Chruszcz, B. and Gunson, K.E. 2001. Effectiveness of highway mitigation fencing at reducing wildlife-vehicle collisions. *Wildlife Society Bulletin* 29:646-653.
- D'Angelo, G.J., D'Angelo, J.G., Gallagher, G.R., Osborn, D.A., Miller, K.V., Warren, R.J. 2006. Evaluation of wildlife warning reflectors for altering white-tailed deer behavior along roadways. *Wildlife Society Bulletin*. 34:1175-1183.
- Dodd, N.L., Gagnon, J.W., Manzo, A.L., Schweinsburg, R.E. Video surveillance to assess highway underpass use by elk in Arizona. *Journal of Wildlife Management* 71: 637-645.
- Ford, A., Clevenger, A.P., Bennett, A. (in press) Comparison of motion-activated camera and trackpad methods of monitoring wildlife crossing structures on highways. *Journal of Wildlife Management*.
- Gunson, K.E., Clevenger, A.P., Ford, A.T., Bissonette, J.A., and Hardy, A. 2009. A comparison of data sets varying in spatial accuracy used to predict the occurrence of wildlife-vehicle collisions. *Environmental Management*. 44:268-277.
- Kleist, A.M., Lancia, R.A., and Doerr, P.D. 2007. Using video surveillance to estimate wildlife use of a highway underpass. *Journal of Wildlife Management*. 71:2792-2800.
- Leclerc, C., and Masson, C. 2003. Abnormally High Power Output of Wind Turbine in Cold Weather: A Preliminary Study. *International Journal of Rotating Machinery*. 9:23-33.
- Mata, C., Hervas, I., Herranz, J, Suarez, F., Malo, J.E. 2005. Complementary use by vertebrates of crossing structures along a fenced Spanish motorway. *Biological Conservation*. 124: 397-405.
- Margalida, A., Ecolan, S, Boudet, J, Bertran, J., Martinez, J., and Heredia, R. 2006. A solar-powered transmitting video camera for monitoring cliff-nesting raptors. *Journal of Field Ornithology*. 77:7-12.
- Mathiasen, R., and Madsen, A.B. 2000. Infrared video-monitoring of mammals at a fauna underpass. *Zeitschrift für Säugetierkunde*. *International Journal of Mammalian Biology* 65:59-61.
- Olsson, M.P.O., Widen, P., Larkin, J.L. 2008. Effectiveness of a highway overpass to promote landscape connectivity and movement of moose and roe deer in Sweden. *Landscape and Urban Planning*. 85:133-139

Parker, I.D., Braden, A.W, Roel, R,L, Nova, J.S, Davis, D.S, Owen, C.B. 2008. Effects of US 1 project on Florida key deer mortality. *Journal of Wildlife Management*. 72:354-359.

Appendix A

Projects using Reconyx Cameras



Project details for wildlife monitoring projects utilizing Reconyx digital cameras(www.reconyx.com)

- 1) Location: Banff National Park
Highway: Trans-Canada highway
Contact: Dr. Tony Clevenger
Email: apclevenger@gmail.com

Project details:

This project has monitored 23 crossing structures consistently for >12 years, 1996–2009 using track-pad monitoring and have obtained over 185,000 crossing events for large mammals including wolves (*Canis lupus*), coyotes, cougars (*Puma concolor*), black bears (*Ursus americanus*), grizzly bears (*Ursus arctos*), deer (*Odocoileus sp.*), elk (*Cervus elaphus*), sheep (*Ovis Canadensis*) and moose (*Alces alces*). Through careful analysis and comparison of different detection methods, this project has determined that remote cameras are the most cost-effective means of conducting crossing structure monitoring.

- 2) Location: Missoula, Montana
Highway: Highway 93S
Contact: Dr. Patricia Cramer
Email: patricia.cramer@usu.edu

Project details:

Four Reconyx cameras (digital systems) have been installed along US 93 South at wildlife crossings that were completed in 2004. These crossings are named Bass Creek North, Bass Creek South, Bass Fishing Access, and Dawn's Crossing. The Bass Creek North camera was installed on October 10, 2008. The three remaining cameras were installed on November 22 and 23, 2008. The cameras have been fully operable during this time period, despite cold temperatures. The batteries have performed very well. In two continuous months of monitoring from late December through mid-February, the batteries still had 73-77% of their charge when the cameras were checked February 15th.

To date, overall, the Dawn's crossing is the most successful of these crossings, with 76 animals passing through the crossing in 84 days (76/84=.90 deer/day). This crossing is open and wide, with a natural soil floor, and almost no human visitation. The least successful crossing is the Bass Creek South Bridge, with no deer recorded in 85 days. The Bass Creek North Bridge did have 10 deer visit in the time span from late October through late November, and only four deer used the passage. The Bass Fishing Access Culvert was more successful, with 36 successful passes by white-tailed deer, and only one repel (of a buck). The summary of all species activities and anecdotal stories are included below.

- 3) Location: Logan, Utah
Highway: Interstate 15, (9 cameras) Interstate 70 (17 cameras), US 6 (9 cameras)
Contact: Dr. Patricia Cramer
Email: patricia.cramer@usu.edu

Project details:

Utah Department of Transportation funded this project which began monitoring in March 2007, and will continue through July 2010. There are 35 cameras in Utah on a number of roads. Thousands of animal pictures per month (don't have finite number). Dominant animal is mule deer, also have seen less than 10 elk, a moose, and meso mammals such as coyote, grey fox, striped and spotted skunks, raccoons, squirrels, jackrabbits.

- 4) Location: Nugget Canyon, Wyoming
 Highway: US 30
 Contact: Hall Sawyer at West-inc.
 Email: hsawyer@west-inc.com

Project details:

In three months of monitoring this project obtained their first photo using Reconyx cameras of pronghorn in a culvert, along with several pictures of elk. The winter migration route of the animals is north to south over this road. There are 6 crossings put in during the summer of 2008, with 6 miles of fence and escape ramps. The box culverts are about 12 feet high and 20 feet wide. As of February 25, we documented 4,697 mule deer, 195 elk, and 1 pronghorn moving through the underpasses.

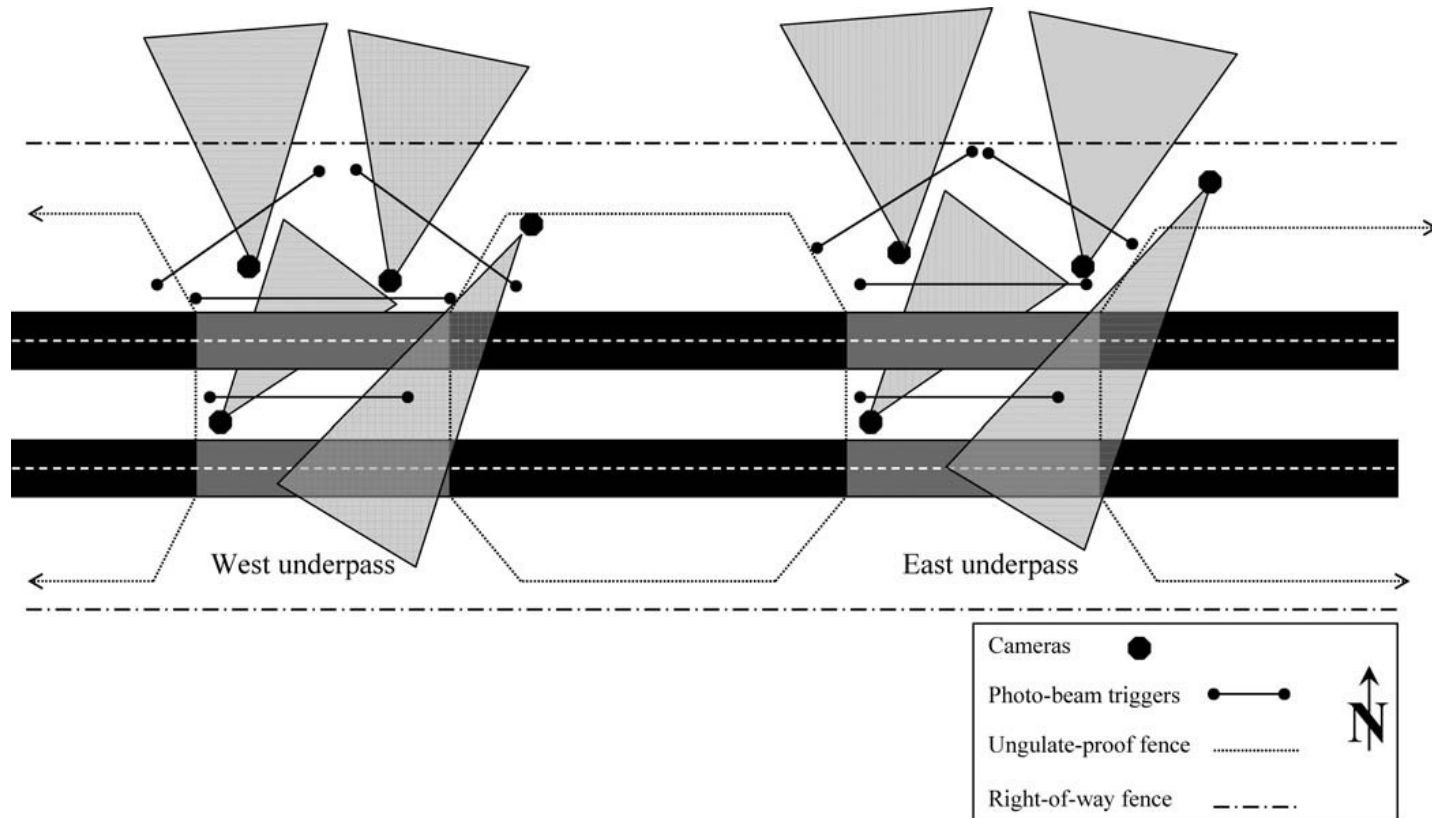
Table 1. Number of mule deer that moved through Nugget Canyon underpasses, north to south and south to north, December 16, 2008 – February 25, 2009.

Mule Deer Movements December 16, 2008 – February 25, 2009								
Underpass	December Deer # (12/16-12/31)		January Deer # (01/01-01/31)		February Deer # (02/01-02/25)		Total	
	North to South	South to North	North to South	South to North	North to South	South to North	North to South	South to North
MP 30.00 BRIDGE	Na	Na	11	0	36	22	47	22
MP 30.50	1458	21	896	146	495	304	2849	471
MP 35.25	68	11	26	14	5	21	99	46
MP 35.96	564	49	112	17	58	39	734	105
MP 37.44	146	2	17	0	31	4	194	6
MP 38.23	16	0	6	0	5	5	27	5
MP 39.00	3	0	1	2	0	2	4	4
MP 40.62	38	9	9	0	7	5	54	30
Total:	2,293	92	1,078	179	637	402	4,008	689

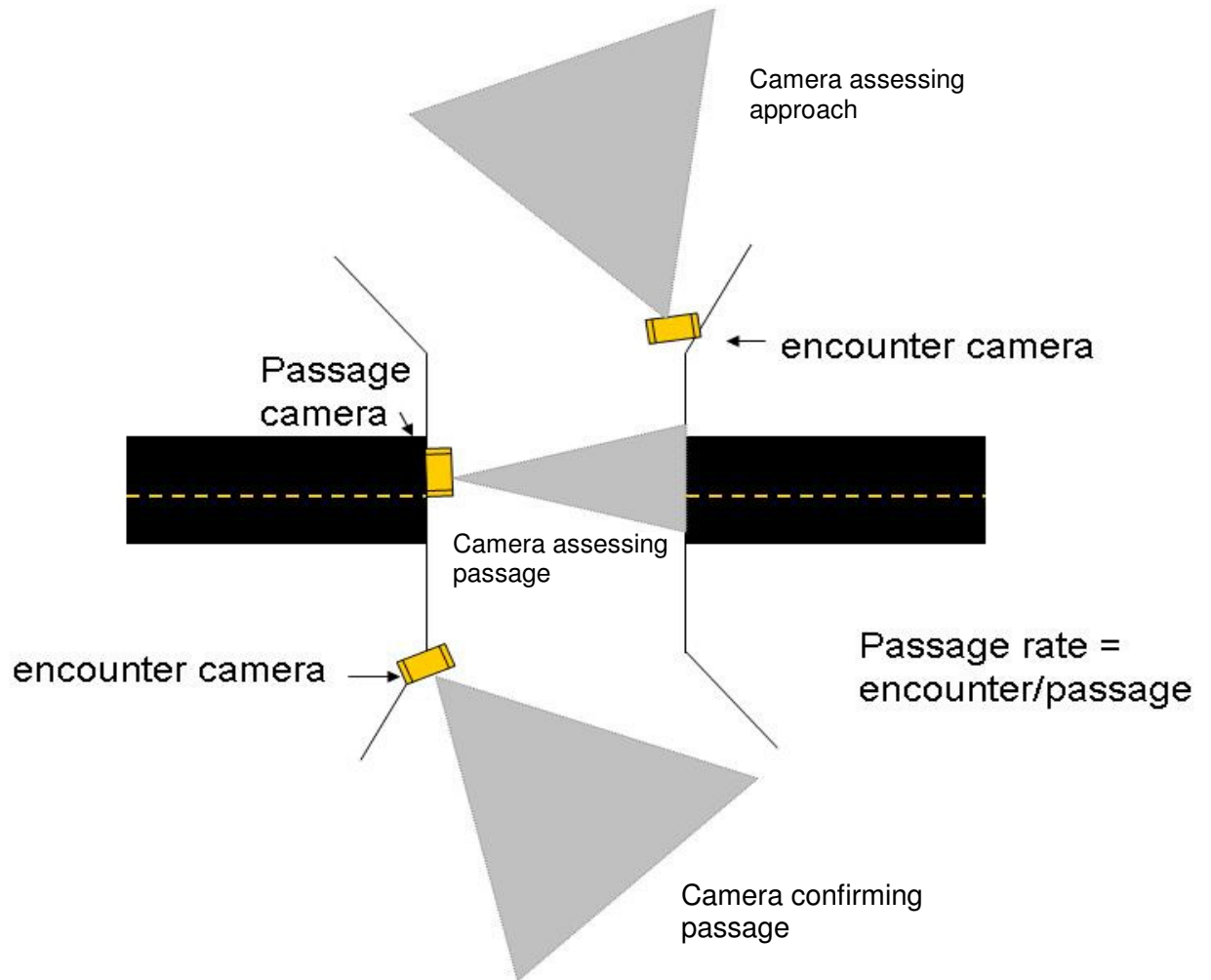
Appendix B

Example of camera (digital or video) set-up

Example of video surveillance at two underpasses (Dodd et al. 2007). Note the 4th camera used to detect traffic volume on the road at the exact same time as the video footage of wildlife crossings.



Hypothetical example of digital or video cameras set-up using 3 cameras to assess passage rate (crossing freq./approach freq.) and avoidance of animals (picture credit: Adam Ford). Note data capture needs to be synchronized with a time stamp on all three cameras to confirm full passage.



Appendix C

Relevant websites

There are many companies that sell camera surveillance equipment, these are a few sites that were looked at for the purposes of this report, and can assist if additional information is required for camera system selection

Camera System Designs

Company	Website	Equipment	Source
Reconyx	www.reconyx.com	Digital systems	Ford et al. (in press)
See More Wildlife	www.seemorewildlife.com	Digital video recorder systems with solar	Internet search
Sandpiper Technologies	http://www.sandpipertech.com	Digital video recorder systems with solar	Kleist et al. (2007)
Solar Power Store	http://findportablesolarpower.com/updates/solar-panels-cold-climates/	Solar panels in cold climates	Internet search

Appendix D

Email Communications

Electrical and Solar powered systems-Jeff Gagnon, Arizona Fish & Game, set-up and built DBM and VEM and VSM systems

Kari,

The AC (power from the grid) was a minimum of 30" (may have even been 36") based on USFS standards, yours may be different in your area. We used a walk behind trencher to achieve this but our furthest distance was maybe 200-300 meters so it would probably not work for 2km (in some cases the electric company can install above ground power distribution lines and poles but this could get spendy) you will also need a professional meter installation (few thousand \$\$).

Solar will be a better option from electrical if you can get enough sun, you also can have an extra bank of batteries to keep charged and switch out to help supplement, we have 6 - 120 lb batteries for each system so you need a few people to do this if you require a system of the same magnitude we use. Like I said, technology may be better now and may not require the same (ours used up to 10 IR lights, 4 cameras, 6 photobeam triggers, 1 vcr, 1 splitter, 1 charge controller as power draws and could suck down the batteries within 3-4 days of no sun)

My address is:

7880 E. Mitchell Dr.
Flagstaff, AZ 86004

Jeff Gagnon
Research Biologist
AZ Game & Fish Dept.
(928) 814-8925
Jeff_Gagnon@Yahoo.com

--- On Mon, 4/13/09, Kari Gunson <kegunson@eco-kare.com> wrote:
Quoting Jeff Gagnon <jeff_gagnon@yahoo.com>:

Hi Kari,

As for solar, we used a combination of both solar and electrical systems tied into the grid. I like the solar system a lot however we probably have quite a bit more sun here and still in the winter we experience occasional downtime.

Depending on the size of the structures, you will need quite a few illuminators, this combined with the power draws of the triggers, cameras, recording device, splitter/multiplexer can draw down a pretty large bank of batteries in a night or so.

The solar systems we used were purchased in 2004 so I would not be surprised if they have some highly efficient systems by now. We are using Reconyx on some other structures along another

highway and they seem very user friendly, one drawback is the ability to monitor approaches to determine passage rates. With a video system we were able to use a 4- camera system, whereas with Reconyx you may need to use 4 single cameras and try to synchronize them. Also, illumination of the site is easier with a solar system.

We had to bury the lines very deep for the AC power (30+ inches) but only 6" for the DC/ Solar, this may vary in your area.

I would look more into the current technology to see if there are solar systems adequate for your area, however may lean toward Reconyx depending on your objectives, they seem to go a long ways on minimal battery power.

Jeff

--- On Mon, 4/13/09, Kari Gunson <kegunson@eco-kare.com> wrote:

From: Kari Gunson <kegunson@eco-kare.com>

Subject: updates

To: doddbenda@cableone.net, jeff_gagnon@yahoo.com

Date: Monday, April 13, 2009, 9:58 AM

Hi Norris and Jeff,

I currently have a job on Highway 69 in N. Ontario to devise a monitoring system on an overpass and a underpass they are building. We are comparing different solar and electrical powered systems. The problem here is there is no electrical power source so I am looking into solar power. There is a study by Kleist et al. that used solar....and I know your system could also run on solar.

How far did you have to bury the cable to obtain power? The closest power source for us is 2 km and they cannot bury easily because it is the Canadian shield! Do you think solar is feasible for a 3-4 camera black and white system with lighting, and remote-triggers. It can be cloudy and cold (-40 C) in winter in this area, but I imagine that there will also be minimal animal movement at the same time.

Take care and hope to see you soon,

Kari E. Gunson, MSc
Road Ecologist/Owner
Eco-Kare International
P.O. Box 51522
Toronto, Ontario
M4E 1C0
cell: 647-519-4080
email: kegunson@eco-kare.com
<http://eco-kare.com>

Assessing Behaviour with DBM systems (e.g. Reconyx cameras)-Patricia Cramer, Utah State University, used DBM systems extensively in western N. America

From: patricia.cramer@usu.edu
To: kgunson@hotmail.com
Date: Fri, 1 May 2009 15:58:19 -0600
Subject: RE: a quick question for you

Yes, Bridget Donaldson did this with white-tailed deer approaches to culverts and bridges in DC and Virginia. The head down is a sign of stress, the continual looking up and down, etc. I don't know about twitches. The overall answer is yes, you can set it up with rapid fire, 10 pics per trigger, and see their behavior. If you go to our wildlifeandroads.org website, look up Donaldson, or click on Virginia, and I believe I have a link to the report.

I am doing similar work with my elk here in Utah. More later. . .

PC
Patricia Cramer, PhD
Research Assistant Professor
Dept. of Wildland Resources
Utah State University
Logan, UT 84322-5290
435.797.1289 (Ph)
patricia.cramer@usu.edu

From: kari gunson [<mailto:kgunson@hotmail.com>]
Sent: Friday, May 01, 2009 1:13 PM
To: Patricia Cramer
Subject: a quick question for you

Hi Patty,

You seem to be a master of Reconyx cameras, going through the pics etc. I was wondering how well you can determine behaviour from them. For example, if you have enough set-up and with proper rapidfire settings can you determine if an elk is alarmed or frightened. Some elk biologists here in Ontario want to ask this type of question, for example they want to measure elk twitches to measure behaviour. Do you think this is necessary to measure their behaviour when using the structures? Can you think of other behaviours of elk that can be measured from RECONYX shots, e.g. grazing vs. running, or ears perked, head up stance vs. slow walk.....

Cheers Kari

Appendix E

Economic Model-available in an excel spreadsheet

Monitoring strategy for wildlife crossings and fencing

Yellow shaded values are estimates and can be changed with additional information and outputs will update accordingly.									
Altering other values may have unintended consequences.									
	Item	Units	Value	DBM	VSM	VWB	VEM	VEH	VEW
Study design	Crossing structures (#CS)	# per circuit	2	~	~	~	~	~	~
	Cameras per structure	# per structure	3	~	~	~	~	~	~
	Circuit distance	kms per circuit	100	~	~	~	~	~	~
	PDA	\$ per computer	500	1	1	1	1	1	1
Camera	**Cameras	\$ per camera	1000	6	6	6	6	6	6
	Memory cards	\$ per card	25	6	6	6	6	6	6
	Infra red trigger	\$ per trigger	50	~	6	6	6	6	6
	Batteries	\$ per battery	1.5	48	~	~	~	~	~
Power Source	Electrical Battery Chargers	\$ per charger	15	2	~	~	~	~	~
	40 watt solar panels	\$ per panel	400	~	6	~	~	~	~
	Wind charger	\$ per charger	995	~	~	2	~	~	~
	Volt Converter	\$ per controller	149	~	6	2	~	~	~
	Volt Regulator	\$ per regulator	149	~	~	~	~	~	~
	Deep-cycle batteries of 55 amp-hours	\$ per battery	150	~	4	4	~	~	~
	*Power Cable	\$ installation	76,000	~	~	~	1	1	1
Transmission	*Bell Communication	\$ installation	20,000	~	~	~	~	1	~
	Wireless	\$ installation	40,000	~	~	~	~	~	1
Software	Visual CE	\$ for software	100	1	1	1	1	1	1
	Microsoft Access	\$ for software	1000	1	1	1	1	1	1

Monitoring strategy for wildlife crossings and fencing

Installation	CBM Installation	hours	80	1	~	~	~	~	~
	Hi Tech power source	hours	200	~	1	1	1	1	1
	Hi Tech transmission	hours	200	~	~	~	~	1	1
Installation	Technician cost (installation-Hi Tech)	\$ per hour	200	~	~	~	~	~	~
	Technician cost (installation-CBM)	\$ per hour	100	~	~	~	~	~	~
Start-up costs (\$)	One time costs	\$		\$15,852	\$51,944	\$50,938	\$124,050	\$184,050	\$204,050
Operating costs (data collection only does not include servicing or data management)	Technician cost (data collection)	\$ per hour	100	~	~	~	~	~	~
	Annual Power Supply	\$ per year	1200	~	~	~	1200	1200	1200
	Annual Communication Supply	\$ per year	1200	~	~	~	~	1200	1200
	Mileage cost	\$ per kilometer	0.48	~	~	~	~	~	~
Circuit time and frequency	Circuit Time	hours per circuit		8	8	8	8	8	8
	Frequency of circuits	one circuit per X days		30	30	30	30	90	90
Circuit costs	Cost per circuit (\$circ)	\$		\$848	\$848	\$848	\$848	\$848	\$848
	Annual circuit costs	\$ per 365 days		\$10,317	\$10,317	\$10,317	\$10,317	\$3,439	\$3,439
Total Annual Circuit + Operating Costs				\$10,317	\$10,317	\$10,317	\$11,517	\$5,839	\$5,839
Hypothetical Study Periods		# of years	1	\$26,169	\$62,261	\$61,255	\$135,567	\$189,889	\$209,889
		# of years	2	\$36,487	\$72,579	\$71,573	\$147,085	\$195,728	\$215,728
		# of years	3	\$46,804	\$82,896	\$81,890	\$158,602	\$201,567	\$221,567

Monitoring strategy for wildlife crossings and fencing

	# of years	4	\$57,121	\$93,213	\$92,207	\$170,119	\$207,406	\$227,406
	# of years	5	\$67,439	\$103,531	\$102,525	\$181,637	\$213,246	\$233,246
	# of years	6	\$77,756	\$113,848	\$112,842	\$193,154	\$219,085	\$239,085
	# of years	7	\$88,073	\$124,165	\$123,159	\$204,671	\$224,924	\$244,924
	# of years	8	\$98,391	\$134,483	\$133,477	\$216,189	\$230,763	\$250,763
	# of years	9	\$108,708	\$144,800	\$143,794	\$227,706	\$236,602	\$256,602
	# of years	10	\$119,025	\$155,117	\$154,111	\$239,223	\$242,441	\$262,441