APPENDIX D – FRAMEWORK FOR MONITORING

Framework for evaluating the performance of measures designed to reduce wildlife–vehicle collisions and barrier effects of roads on wildlife movement. Numbers for monitoring questions relate to one another across columns. Black text = Monitoring generally associated with highway corridor; Blue text = Monitoring and research needed to answer management questions from the project area at the landscape scale.

MONITORING OBJECTIVES	Monitoring question	Methods	Study design	Targets
WILDLIFE–VEHICLE COLLISION REDUCTION (PRE- AND POST-CONSTRUCTION)	1. Do crossing structures reduce mortality rates? 1.a. Compared to baseline levels of road mortality; 1.b. Compared to adjacent "control" areas post-construction; 2. Compared to other sections of highway without crossing structures 3. What is the incidence of mortality among a marked sample? [Addressing this question will require large sample sizes and representative sampling of population]	Road-kill data collection: 1 & 2. Road-kill surveys on highway sections with and without crossing structures. Surveys must be extensive in length (see Feldhamer et al. 1986) and systematically conducted at frequent intervals Radiotelemetry: 3. Standard capture-mark-release techniques. Transmitters may consist of VHF transmitters or global positioning system (GPS) transmitters with the latter providing more spatial accuracy in identifying how and where animals cross highways.	Road-kill data collection: 1.a. (1) Pre- vs post-construction comparison of mortality rates on "treatment" areas (crossing structures) with "controls" (BACI[1] design) 1.a. (2) Pre- vs post- construction comparison of mortality rates on "treatment" areas (crossing structures) and those without "controls (BA[1] design)" 1.b. Post-construction comparison of mortality rates using "treatment" (crossing structures) sections vs. adjacent sections without crossing structures (CI[1] design) 2.a. Multivariate logistic regression analysis 2.b. Comparison of mortality rates on sections with and without crossing structures, standardized by highway length Radiotelemetry: 3. Proportion of marked sample killed on highway compared to control sections	1 & 2. Reduction in mortality rates compared with baseline conditions (i.e., without crossing structures). Reductions should either be statistically significant or deemed biologically meaningful. 3. Significant (statistical or biological) proportion of the marked sample survives and reproduces in highway environment with crossing structures.

MONITORING OBJECTIVES	Monitoring question	Methods	Study design	Targets
RESTORING MOVEMENTS IN PROJECT AREA (PRE- AND POST-CONSRUCTION)	1. What is the frequency of movement across highway with crossing structures and without? 2. What factors influence crossing activity? 3. Do animals cross above-grade or use existing below-grade structures? 4. Where do animals cross the highway 5. What is the genetic structure of focal populations and what are barriers to gene flow? 6. Is the demographic structure of focal population affected by the highway?	Telemetry (radio or GPS): 1.2.3.4. (See above) Observational data: 3 & 4a. Remote cameras that detect and record animal activity in highway environment over 24-hr period. Remote digital 35mm or video cameras installed on preferably straight and level sections of highway. Some video cameras detect and record animal activity on sections up to 1.0 mile in length 3 & 4b. Trackpads on right-of-way (Hardy et al. 2007) 3 & 4c. Fluorescent dye marking. Method allows for follow-up "tracking" of small animal using ultraviolet light at night (McDonald and Cassady St Clair 2004) 5. Non-invasive genetic sampling methods (e.g., hair snares, scat dogs) 5a/5b. Genetic sampling and genotyping; assignment tests and other spatial genetics modeling approaches 5c. Genetic sampling and genotyping; genetic health analyses (inbreeding, allelic diversity, heterozygosity values);	Telemetry: 1. Frequency of radio-marked animal movements across highway sections using treatment/control; BACI & CI designs or treatment; BA design 2. Frequency of radio-marked animal movements across highway related to traffic volumes and time of day 3 & 4. Radio monitor closely movements in highway environment and existing below-grade passage structures Observational data: 5. Non-invasive genetic sampling surveys on established survey points or transects in study area. 5a/5b. Model (based on maternally inherited mitochondrial markers) landscape resistance that correlate with the genetic structure of the target species 5c. Compare the genetic diversity of treatment (highway) populations to control populations (that are stable or declining)	1. Greater number of marked individual movements occur on treatment sections (crossing structures) 2. Traffic volume, intra-group behavior and time of day may help explain movement behavior and crossing success 3 & 4. Significant (statistically or biologically) greater number of individual movements of radio marked individuals occur on treatment sections (wildlife crossing structures) 4. Greater number of observed crossings occur on treatment sections (crossing structures) compared to control sections 5a. Landscape resistance models will identify both barriers to dispersal and corridors for gene flow (pre- and post-construction) 5b. Distinguish exploratory movements from the successful reproduction and reveal the resistance of a landscape to gene flow 5c. Reveal whether genetic variability has reached critically low levels

MONITORING OBJECTIVES	Monitoring question	Methods	Study design	Targets (Applications)
POPULATION VIABILITY (POST-CONSTRUCTION)	Do project connectivity measures affect key life-history attributes (e.g., mortality, fertility, survival to reproduction, connectivity) and provide for natural sustaining populations in the project area?	<u>Spatially-explicit population viability modeling</u>: Development of spatially-explicit, individually-based population viability (PV) models using demography data and habitat data collected for other project objectives or obtained from the scientific literature. Use of custom or commercially available PV modeling software (e.g., RAMAS-GIS). Robust demography and spatially-explicit landscape suitability information will be required for such an approach.	<u>Spatially-explicit population viability modeling</u>: Modeling of PV under (a) baseline conditions, (b) highway without wildlife crossings, (c) highway with wildlife crossings	<u>Spatially-explicit population viability modeling</u>: Determination of the mean and variation of demographic parameters necessary to maintain viable populations over the long term; provides different modeling scenarios by varying performance targets, refining target parameters and creating new monitoring questions based on predictions, and future PV models

MONITORING OBJECTIVES	Management question	Methods	Study design	Targets
FENCE INTRUSIONS (POST-CONSTRUCTION)	1. How often do individual animals breach the fence and access the right-of-way? 2. Where do fence intrusions occur, for what species, and how frequently?	<u>Observational data</u>: 1 & 2. Road surveys or opportunistic observations of wildlife inside the highway fence. Can be conducted by both WTI researchers or DOT personnel using PDA/GPS ($ROCS^2$) units	<u>Observational data</u>: 1 & 2. Summary of fence intrusion data by species, frequency, and location	1. Minimize number of fence intrusions by wildlife 2. Evaluate effectiveness of fence construction and design at various points in study area, including effects of physical and biological factors (e.g., terrain, habitat, snowfall) on intrusion frequency
JUMP-OUTS (POST-CONSTRUCTION)	1. When wildlife breach the fence and access the right-of-way, do they find the jump-outs? (see "fence intrusions") Of those that visit the jump-out, what proportion exit the right-of-way by using the jump-out? 2. What species visit the jump-outs, how frequently, and how often are they successfully used?	<u>Observational data</u>: 1 & 2. Systematic visits to jump-outs when monitoring wildlife use of crossings. Can be conducted by both WTI researchers or DOT personnel using PDA/GPS ($ROCS^2$) units	<u>Observational data</u>: 1 & 2. Summary of jump-out visits and use data, by species, frequency, and jump-out location	1. Minimize the number of wildlife visits to jump-outs (see "fence intrusions") 2. Maximize the use of jump-outs for safe exit from the highway right-of-way

MONITORING OBJECTIVES	Management question	Methods	Study design	Targets
WILDLIFE CROSSING DESIGN (POST-CONSTRUCTION)	1. Are animals crossing highway using existing below-grade structures (culverts)? 2. Do animals use the wildlife crossing structures? With what frequency? 3. What are the attributes of existing below-grade structures and wildlife crossings that influence species-specific passage?	Observational data: 1 & 2. Noninvasive detection methods (e.g., track beds, track plates, hair snares, remote cameras) to quantify species-specific use. 3a. Detection stations and/or transects 3b. Data summary; multivariate analysis; occupancy modeling	Observational data: 1 & 2. Employ non-invasive survey methods with sufficient ability to detect species with high probability. 3. Develop species-specific expected use values for calculating performance indices	1. Level of connectivity afforded by existing below-grade structures 2. Level of connectivity afforded by wildlife crossings 3a/3b. Data on species-specific design requirements of below-grade structures (culverts) and wildlife crossings 3c. Adaptive management of future connectivity design plans
SPECIES OCCUPANCY (project-level) (PRE- AND POST-CONSTRUCTION)	1. What species are present - absent in the highway corridor project area? 2. How are species" distributed and what are their relative abundances? How do distribution and relative abundance change over time? 3. Can species occupancy models be developed to accurately predict occurrence in subregions of the project area?	Species detection surveys: 1. 2. 3. Species occupancy methodology. Detection stations and transects located at project-level 1a 2a 3a. Non-invasive detection methods (e.g., track plates, hair snares, remote cameras, scat detection dogs) 3. Species occupancy modeling	Species detection surveys: 1. 2. 3. Fixed system of survey points-transects in highway corridor and adjacent habitats. Repeat monitoring within a relatively short time period (e.g., 10-14 d) to ensure demographic closure. Conduct surveys 1-3 times each year (season?) over long-term.	1. Assess species presence-absence or use of project area 2. Evaluate (a) which species are present in project area and, (b) site colonization and extinction estimates if multiple-year datasets are compiled 3. Occupancy assessment provides (a) information related to "expected" use of wildlife crossings and more accurate performance indices for design-related analysis; (b) species occurrence probability surfaces

MONITORING OBJECTIVES	Research question	Methods	Study design	Targets
SPECIES OCCUPANCY (landscape-level) (PRE- AND POST-CONSTRUCTION)	1. What species are present - absent in the greater project area? 2. How are species" distributed and what are their relative abundances? How do distribution and relative abundance change over time? 3. Can species occupancy models be developed to accurately predict occurrence across the greater project area?	Species detection surveys: 1. 2. 3. Species occupancy methodology. Detection stations and transects located at landscape-level 1a 2a 3a. Non-invasive detection methods (e.g., track plates, hair snares, remote cameras, scat detection dogs) 3. Species occupancy modeling	Species detection surveys: 1. 2. 3. Fixed system of survey points-transects in study area. Repeat monitoring within a relatively short time period (e.g., 10-14 d) to ensure demographic closure. Conduct surveys 1-3 times each year (season?) over long-term.	1. Assess species presence-absence or use of greater study area 2. Evaluate (a) which species are present in greater study area and, (b) Site colonization and extinction estimates if multiple-year datasets are compiled 3. Occupancy assessment provides (a) information related to "expected" use of wildlife crossings and more accurate performance indices for design-related analysis; (b) species occurrence probability surfaces

[1] BACI: Before-After-Control-Impact; BA: Before-After; CI: Control-Impact (see Roedenbeck et al. 2007).
[2] ROCS: See description in Chapter 3.