Oyu Tolgoi Roads and Wildlife Mitigation Report

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Executive Summary

Currently a 106.8 km-long road from the Oyu Tolgoi (OT) mine site (southern Gobi, Mongolia) to the Gashuun-Sukhait (GS) border crossing is in the process of being upgraded to asphalt for copper concentrate export. The majority of the road length aligns with the national highway alignment and will be adopted by the Government of Mongolia. The road is predicted to result in substantial impacts on priority biodiversity features including khulan (*Equus hemionus*), black-tailed gazelle (*Gazella subgutturosa*), argali (*Ovis ammon*) and Mongolian gazelle (*Procapra gutturosa*). The upgrade project presents critical and high risks for khulan, black-tailed gazelle, and argali through direct and indirect habitat loss and poaching through increased access for humans into the area. Road and railroads in different parts of the Gobi already affect these desert ungulates through direct and indirect habitat loss, indirect mortality (i.e. poaching through increased human access to the area), and the barrier effects associated with infrastructure. The most notable other infrastructure in the immediate vicinity is an existing coal haul road (Energy Resources road), and, much further to the east, the Trans-Mongolian railroad. To comply with lender requirements and also achieve a Net Positive Impact to which OT has committed, the OT-GS Road upgrade project is required to effectively mitigate the predicted effects of the road on wildlife. Recommendations in this report focus on measures aimed at providing safe crossing opportunities for wildlife, particularly for desert ungulates.

We reviewed available documents and literature, visited the OT mine site and surrounding OT roads in February, 2013, and had numerous discussions with experts in the region and OT staff and consultants. This, with the team's prior expertise in mitigating wildlife impacts of roadways, was used to develop this report. The report contains a summary of the current status of wildlife impacts of the OT roads and planned mitigations (Chapters 1-4), a review of the most promising mitigations and mitigations previously proposed for the OT roads (Chapter 5) and a set of recommendations specific to wildlife crossing structures on the OT-GS Road (Chapter 6). More detail on specific recommendations can be found in Chapters 5 and 6. A brief summary of the recommendations made by the research team is provided below.

The Oyu Tolgoi Company should be recognized for their commitment to a net positive impact on biodiversity. Efforts made by OT in this region could have a lasting impact on protection of endangered species. Further, the efforts by OT could set the standard for future infrastructure projects in the region.

The 12 meter wide (minimum width) wildlife underpasses that were originally proposed for the OT-GS road, particularly with no features to guide animals to the structure, are likely to fail in mitigating the fragmentation effect of the road for the target species. We suggest that wildlife crossing structures be constructed based on a phased approach.

- Phase 1A includes immediate design and construction of several wildlife crossing structures in the central valley area. This Phase could include six wildlife crossing structures of varying size and type at three sites. The proposed study design includes three locations (crossing locations 7, 8 and 9, Figure 35), each location with two crossing

structures. Each location will have an underpass and an overpass of similar width. This comparative approach to the initial phase of construction will provide evidence-based data for the planning and designing for later phases. Construction of phase 1A should preferably be implemented as soon as possible.

- Phase 1B includes the design and construction of two wildlife crossing structures, and adding features (e.g., fencing and visual barriers) to a 10 m bridge currently under construction. These three structures are in the granite outcrop area. This phase could be implemented soon, but only if it does not impede the progress of phase 1A.
- Phase 2 includes the design and construction of additional wildlife crossing structures, both in the granitic outcrop area close to the OT mine and in the central valley. This phase should be informed through the monitoring of phase 1A and 1B.
- Phase 3 includes wildlife crossing structures in the Small Gobi B strictly protected area. This phase should only be implemented as part of a comprehensive wildlife mitigation plan for all transportation infrastructure in this area.

In addition to the phased implementation of wildlife crossing structures, we recommend that OT:

- Develop a monitoring plan for phase 1A structures (and also for phase 1B)
- Continue to support baseline fauna surveys
- Continue OT roadkill recordkeeping
- Develop an anti-poaching program that includes regulations, enforcement and public education
- Develop a public education program for wildlife issues
- Install and maintain warning signs on livestock crossings
- Continue OT vehicle speed monitoring

We recommend implementing barriers, intended to keep vehicles from leaving the road, only in conjunction with wildlife barriers and visual barriers near wildlife crossing structures. We do not recommend treating the entire length of any of the OT roads with these barriers.

Refer to Chapter 6 for detailed design recommendations for the wildlife crossing structures and associated features. The most important recommendations are summarized here:

- We currently have insufficient data to evaluate the currently proposed 16 structures (minimum number) with a 6 km spacing distance. However, we recommend that the number of crossing structures and spacing be revisited if more data are available (e.g. wildlife movement data, population viability modeling, data on the use of different types and dimensions of crossing structures).

- Wildlife crossing structures, whether overpasses or underpasses, should be open with very gradual approaches and a clear line of sight for wildlife that is at least several hundreds of meters across the crossing structure.
- Visual barriers to hide traffic from animals should extend for 500 m on either side of the crossing structure. Wildlife barriers and barriers to keep vehicles from driving off-road should be implemented in the immediate vicinity of the structures. These three items (visual barriers, wildlife barriers and motor vehicle barriers) would best be combined into one design element.

1 INTRODUCTION

The long-distance movements of nomadic and migratory ungulates are one of the most spectacular examples of ecosystem processes in action and have existed for thousands if not millions of years (Berger et al. 2006). These movements, however, are increasingly endangered due to the fragmentation effects of human activities (Berger 2004). Fragmentation splits populations into smaller subpopulations, reducing landscape connectivity and reducing regional population size and population persistence over the long term (Saunders et al. 1991, Harrison & Bruna 1999). For nomadic or migratory species, fragmentation can limit access to key resources and lead to local or regional extinctions.

Rivaling the Serengeti-Mara ecosystem, the Central Asian grasslands and semi-deserts is one of the largest remaining ecosystems where ungulates move over long distances. Southern Mongolia remains one of three areas of Eurasia that still hold viable communities of nomadic or migratory ungulates (Kaczensky et al. 2006, Mallon & Jiang 2009). The movements of Mongolian gazelles (*Procapra gutturosa*) and Asiatic wild ass or khulan (*Equus hemionus*) surpass 1000 km per year in many cases (Ito et al. 2006, Kaczensky et al. 2011, Mueller et al. 2011). The current global and Mongolian distribution of these two ungulates is a fraction of their historic range (Kaczensky et al. 2006). Grasslands and semi-desert ecosystems of southern Mongolia are the last intact habitat of khulans, where roughly 80% of the global population resides (Kaczensky et al. 2006, Moehlman et al. 2008).

Khulan and other nomadic or migratory ungulates are currently facing potentially severe habitat fragmentation and loss (Lkhagvasuren et al. 2011). Recent studies have shown that habitat is being fragmented by roads, railways and fencing along the international border with China (Ito et al. 2005, 2006, 2013; Olson et al. 2010, Kaczensky et al. 2011). New transportation infrastructure (road and rail) related to existing and new mining projects will create additional barriers in the critical habitat of these ungulates (TBC & FFI 2011, Lkhagvasuren et al. 2011).

An 106.8 kilometer (km) road from the Oyu Tolgoi mine site to the Gashuun-Sukhait border crossing (OT-GS Road) is in the process of being upgraded to asphalt for copper concentrate export. The majority of the road length aligns with the national highway alignment and will be adopted by the Government of Mongolia. Before the road upgrade the existing road was used for local transportation, trade, and to access the border crossing at Gashuun-Sukhait. Before and during the road upgrade the earth road was also used by Oyu Tolgoi to transport materials from China. For this purpose the existing road was improved through grading. Currently different sections of the road are being rebuild and the surface is being paved. Both Oyu Tolgoi, LLC (Oyu Tolgoi or OT) and the public will be able to use the road. The sphere of influence of the OT-GS Road comprises the direct footprint of the road upgrade plus its indirect impact zone. For nomadic and migratory ungulate species, this has been conservatively estimated to be a distance of up to 5 km from the road (ESIA 2013).

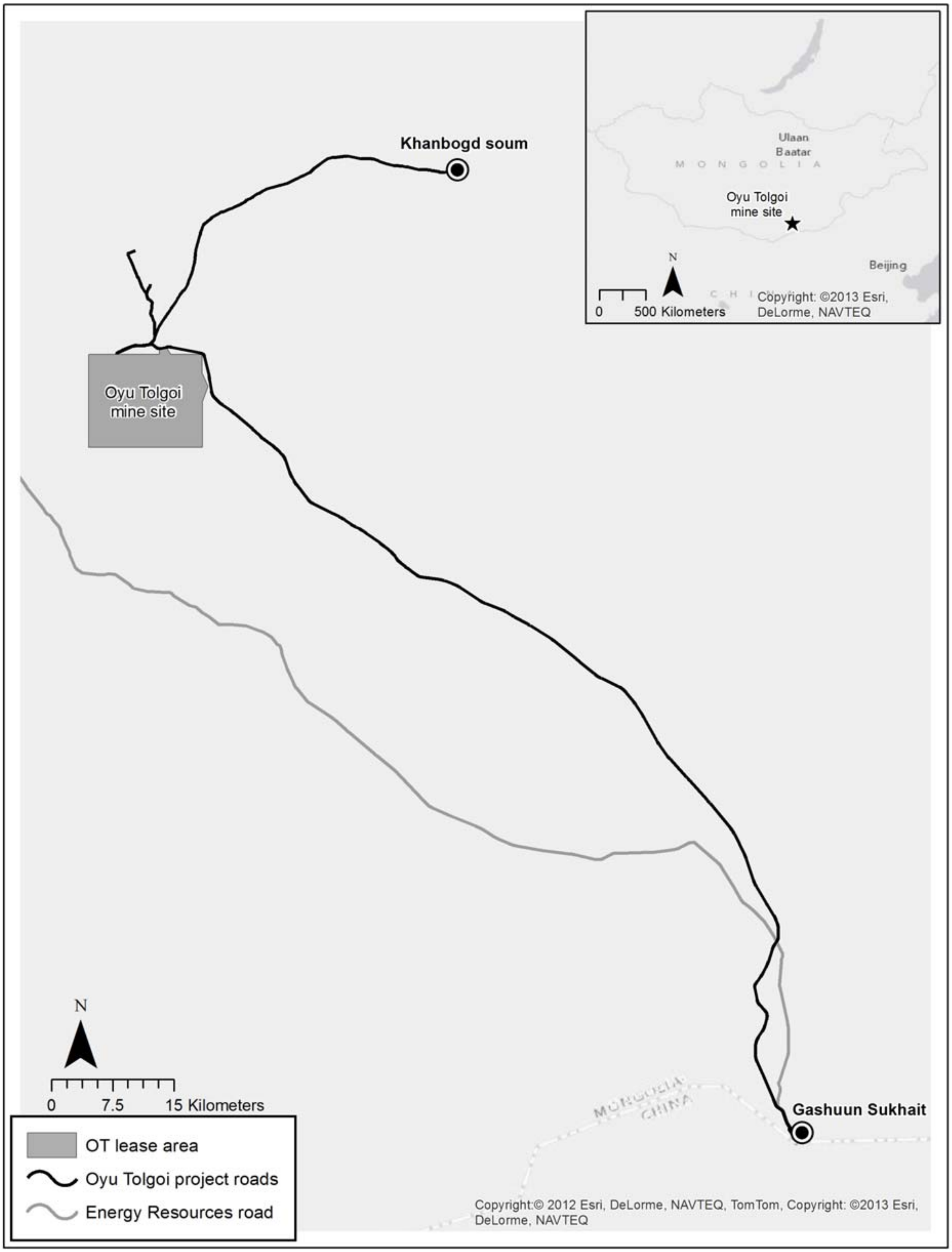

Figure 1: Location project area in the Gobi in southern Mongolia

The OT-GS Road, as currently planned, is predicted to result in substantial impacts on priority biodiversity features including khulan, black-tailed gazelle (*Gazella subgutturosa*), argali (*Ovis ammon*) and Mongolian gazelle (ESIA 2013). The upgrade project presents critical and high risks for khulan, black-tailed gazelle, and argali through direct and indirect habitat loss and poaching through increased access for humans into the area (ESIA 2013). Road and railroads in different parts of the Gobi already affect these desert ungulates through direct and indirect habitat loss, indirect mortality (i.e. poaching through increased human access to the area), and the barrier effects associated with infrastructure. The most notable other infrastructure in the immediate vicinity is an existing coal haul road (Energy Resources road; Figure 1), and, much further to the east, the Trans-Mongolian railroad. To comply with lender requirements and also achieve a Net Positive Impact to which OT has committed (see Chapter 2), the OT-GS Road upgrade project is required to effectively mitigate the predicted effects of the road on wildlife (ESIA 2013). Suggested measures include wildlife overpasses and underpasses for wildlife, measures that discourage vehicles from leaving the road at will, training of OT personnel with regard to minimizing impacts on wildlife (general information, no littering, speed limits, minimize off-road parking of vehicles, no poaching), speed limit enforcement, and placing wildlife warning signs (ESIA 2013).

Fragmentation of wildlife populations from highways and vehicles that travel on them can be mitigated by using appropriately designed mitigation measures, such as wildlife underpasses and overpasses (Iuell et al. 2003, Gagnon et al. 2011, Clevenger & Huijser 2011). Despite wildlife crossing mitigation having been effective at mitigating fragmentation effects of roads elsewhere, their use by nomadic or migratory ungulates in open environments remains largely untested. There is some uncertainty over whether khulan, black-tailed gazelles, argali, and Mongolian gazelles will use overpasses or underpasses, and if they do how many individuals will use them. However, wildlife use of properly located and appropriately designed wildlife crossing structures (correct type, correct dimensions) has been very substantial elsewhere, including for a wide variety of ungulates (e.g. Gagnon et al. 2011, Clevenger & Huijser 2011).

The purpose of this report is to provide recommendations for mitigating the barrier effect of the OT-GS Road for a range of nomadic, migratory, and seasonally abundant ungulate species inhabiting the Southern Gobi desert ecosystem of Mongolia. Specifically, the report will provide the basis for mitigation plans for the OT-GS Road, provide detailed technical information on location and design of proposed wildlife crossing structures, and other mitigation measures aimed at reducing direct and indirect effects of the road on ungulate populations. This report also contains recommendations for reducing the impacts of the Oyu Tolgoi-Airport Road (OT-Airport Road) and the Oyu Tolgoi-Khanbogd Road (OT-KB Road) on wildlife, but potential wildlife underpasses and wildlife overpasses for these roads are not part of the current assignment for the researchers. Thus this report mainly focuses on mitigating the barrier effect of the OT mine site's road network on desert ungulates, with an emphasis on the OT-GS Road.

2 OYU TOLGOI BIODIVERSITY COMMITMENTS AND NET POSITIVE IMPACT POLICY

2.1 Biodiversity Commitments

To adhere to commitments that the OT Project has made to have a Net Positive Impact on biodiversity, mitigation measures proposed for the OT-Airport, OT-KB and OT-GS roads have been described in several documents. The primary document is the Environmental and Social Impact Assessment (ESIA); Appendix 3 describes the biodiversity impacts and mitigation actions for the OT Project (TBC & FFI 2012a). Appendix 3 also enumerates the major potential impacts of the OT Project on biodiversity and gives the details for the actions that OT Project is committed to make. The mitigation actions from Table 6 of the ESIA for all “critical and high risk” impacts pertinent for the OT Roads and Wildlife Mitigation Report are (TBC & FFI 2012a):

- Deter vehicles leaving the OT-GS, OT-KB, and OT-Airport Roads at will, without hindering wildlife crossings, or livestock crossings, particularly at designated livestock crossing locations.
- Take action to increase driver awareness of wildlife on, and near, the road, impacts of roads and traffic on wildlife, and mitigation measures taken to reduce these impacts.
- Install warning signs along the roads to warn drivers of the risk of collision with wild animals.
- Enforce low speed limits of OT vehicles on sealed and unsealed roads on and off the lease lands (speed limits for OT vehicles will be reviewed in consultation with a wildlife expert).

Appendix 3 of the ESIA also provides the rationale for the construction of appropriate and sufficient underpasses for the OT-GS Road. It was originally suggested that an underpass would be needed approximately every 6 km along the OT-GS Road to ensure permeability for khulan and the two gazelle species in the affected zone (ESIA 2013). The underpasses were envisioned to be at least 12 m wide (road length) and 4.5 m high. Lastly, there was also a call for solid sides (a visual barrier) along the top of the crossing structures, so that animals using the underpasses would not see vehicles or their headlights on the road above them as they approached the underpasses.

A list of onsite mitigation measures have been proposed or suggested for implementation (ESIA 2013). This includes “underpasses” (OTP 2012).

(i) develop a work plan (acceptable to lenders) for the installation of underpasses, which will include activities/timelines for stakeholder consultation, design, locations, engineering, environmental assessment in each case in a manner consistent with expert advice from the Western Transportation Institute (WTI), to facilitate compliance by the Project Company with the International Finance Corporation, World Bank Group’s (IFC’s) Performance Standard 6 which requires its client to meet throughout the life of the investment Biodiversity Conservation and Sustainable Management of Living Natural Resources and the European Bank for Reconstruction and Development's Performance Requirement 6 for Biodiversity Conservation and Sustainable Management of Living Natural Resources, and the objective of Net Positive Gain; and

(ii) implement and complete underpass construction and other works as required by such work plan.

To adhere to these mitigation actions and commitments, the OT Roads and Wildlife Mitigation Report will address each of these action items in detail via its analyses and recommendations. New information in the report will help update and make more specific - spatially and structurally - the wildlife mitigation measures, as well as describe the relative effectiveness of the best available mitigation measures to decrease off road vehicle departures from the OT roads.

2.2 Net Positive Impact for the OT-GS Road Upgrade

A Net Positive Impact (NPI) forecast is a projection of potential biodiversity losses and gains over a period of time in the future (25 years in this case, i.e. 2011-2036), based on current knowledge regarding OT Project impacts, potential offset activities, characteristics of priority biodiversity features, and background rates of biodiversity loss and threat in the region. To achieve NPI for the OT-GS Road, the road mitigation measures need to achieve substantial permeability, i.e., mitigate fragmentation effects of the road and the zone adjacent to the road, and provide functional demographic and genetic connectivity (TBC & FFI 2011).

One of the impacts of the OT Project on wildlife is likely to be the fragmentation of habitat and animal populations. The presence of the road, the increase in traffic volume, traffic speed and human disturbance in a zone adjacent to the road is likely to affect the movements of large mammals (ESIA 2013). Fragmentation effects will occur for all terrestrial species to some degree but will have the most damaging effects primarily for the large ungulates that are the focal species for this project: khulan, black-tailed gazelle, argali, and (to a lesser extent) Mongolian gazelle, for which the project area is at the edge of its range. Direct mortality from collisions with vehicles is not expected to be a factor affecting ungulate populations due to the relatively low traffic volume on the OT-GS Road. However, should vehicle-caused mortality become an issue on the OT-GS Road, once in operation, appropriate mitigation should be taken to reduce risks of further road mortality (see Chapters 5 & 6).

There are insufficient baseline data to assess the performance of the road mitigation measures and objectively examine whether the road is sufficiently permeable to ungulates and whether the mitigation measures along the road resulted in or contributed to a NPI. There were some fauna surveys conducted in 2003, and more were started in 2009. Currently more extensive ground and aerial surveys are being undertaken for desert ungulates (i.e. khulan and black-tailed gazelle).

If the road upgrade does not include appropriate mitigation measures, WTI researchers expect that the OT-GS Road and its projected increase in traffic will become a functional barrier to the focal ungulate species identified for the project, although some individuals are still likely to cross. To conclude, if the mitigation measures have partially or fully mitigated the barrier effect of the OT-GS Road, there will need to be evidence that the movements of khulan and black-tailed gazelle across the road have been maintained or have been restored. Assessing these impacts and the mitigation measures' performance are best done when comparing movements post-mitigation with the baseline data obtained prior to mitigation in a Before-After-Control-Impact (BACI) study design (Roedenbeck et al. 2007, McCollister and Van Manen 2010). In light of the lack of such baseline information, performance assessments may need to make use of GPS radio collars on the ungulate species, or reference values will have to be obtained from another source.

Summary:

- The OT project has made a commitment to have a net positive impact (NPI) on biodiversity.
- To that end, wildlife mitigation actions identified in the ESIA include:

1. Deterring vehicles from leaving the road
2. Increasing driver awareness of wildlife issues
3. Installing wildlife warning signs
4. Enforcing speed limits on OT vehicles
5. Appropriate and sufficient wildlife underpasses are constructed along the OT-GS Road

- Baseline data from fauna surveys is needed in order to determine NPI for mitigations along the OT-GS Road.

3 CURRENT STATUS OF WILDLIFE ISSUES SURROUNDING OYU TOLGOI ROAD MITIGATION

3.1 Current OT Road Information Pertinent to Wildlife Mitigation

Mitigation measures for wildlife are to be considered for the three roads or road sections of the OT mine site's road network: OT-GS Road (from the OT mine to Gashuun Sukhait, at the border with China), OT-Airport Road (from the OT mine to the airport), the OT-KB Road (from the OT mine to Kahnbogd). The last 16 km of the OT-GS Road are in, adjacent to, or close to the Small Gobi B strictly protected area (Small Gobi B SPA) (Figure 2, Figure 3, and Figure 4). Characteristics of these three roads are presented in Table 1.

Table 1: The three roads or road sections associated with the Oyu Tolgoi mine site.

Road section	Length (km)	Road width (m)	Road surface	Traffic volume (2011)	Projected traffic volume (2030)	Current speed limit (km/h)	National highway (after improvements)
OT-GS	106.8	8 (excl. 3 m verge on either side)	Gravel (in process of being paved)	388 (TBC and FFI 2011)	>1600 (TBC and FFI, 2012)	60	Yes
OT-Airport	8.6 (excl. spur roads)	12	Gravel (may or may not be paved later)	N/A[1]	N/A	60 (some sections 40 km/h)	Yes
OT-KB	39.8	12	Gravel (may or may not be paved later)	N/A	N/A	80	Yes

[1] N/A: information not available

The three roads were unpaved or gravel roads before the road improvements related to OT were initiated. Other linear infrastructure in this area not considered by this report includes the Energy Resources road that connects the Tavan Tolgoi coal mine (to the northwest of OT mine site) to the OT-GS Road near the border with China, a power line from the Mongolian/Chinese border to OT mine site, and a water pipeline from an area north of Khanbogd to the OT mine site. The Energy Resources road is a paved toll road for coal trucks that connects the Tavan Tolgoi mine site to the border and passes through a portion of the Small Gobi B SPA. In addition there is a complex of gravel and dirt roads associated with the paved toll road (not on the map in Figure 2) for coal trucks that do not want to pay the tolls or that are overloaded and are not allowed to drive on the toll road. The toll road and parallel complex of gravel/dirt roads are associated with the Tavan Tolgoi coal mine north-east of Dalanzadgad, and are not part of OT’s wildlife mitigation project.

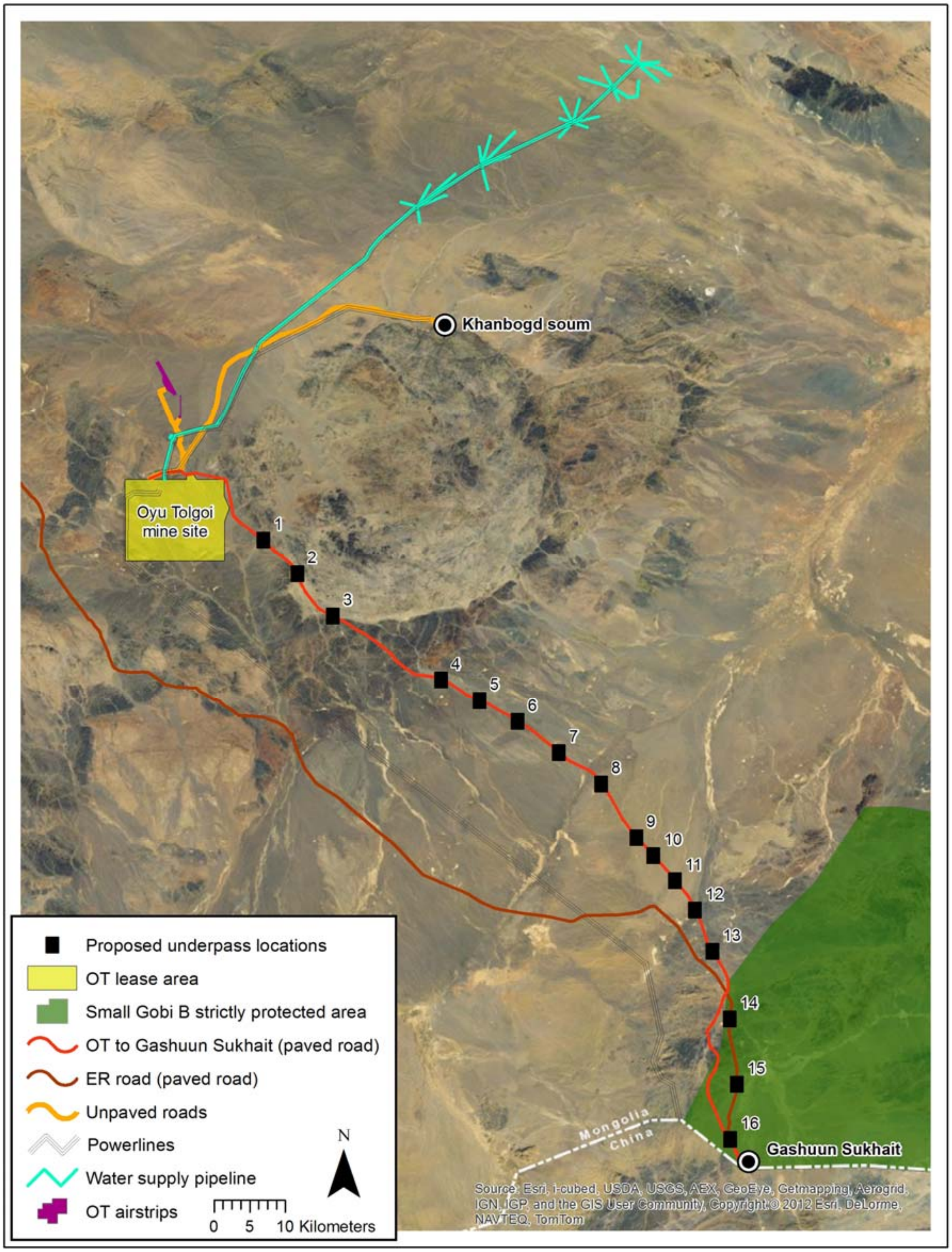

Figure 2: The roads, power line and water pipeline in the study area. (Source: Oyu Tolgoi, LLC). Note that the "proposed" underpass locations are based on OT data. The current document contains different recommendations (see Chapter 6 and 7).

Figure 3: Finished and unfinished road section from Oyu Tolgoi mine site to Gashuun-Sukhait border crossing with China, Gobi, Ömnögovi, Mongolia (© Marcel Huijser). The paved road in the foreground is finished. Here the finished road transitions into a section that is still gravel and unfinished (background behind road closure sign).

Figure 4: Gravel road from Oyu Tolgoi mine site to Khanbogd, Gobi, Ömnögovi, Mongolia (© Marcel Huijser).

3.2 Domestic Animals and Springs, Camp Locations, etc. and Livestock Crossings with Maps of the OT-GS Road

The OT roads system and other linear infrastructure cut through traditional grazing areas for livestock in the study area. The roads not only affect livestock safety, but also impact management activities of the livestock herders. The domestic livestock include sheep, goats, cattle, horses and Bactrian camels. The domesticated Bactrian camel is reported by herders to have difficulty walking up steep grades that may be associated with road beds (though, based on field observations, the researchers very much doubt if the sometimes steep grades associated with the roadbed are indeed a substantial barrier to this species). Regardless, 21 livestock crossings have been provided along the OT-GS Road (Figure 5, and Figure 6). A livestock crossing is a zone (perhaps about 10-20 m in road length) where there are gentle slopes on both sides of the road surface. The gentle slopes should allow for Bactrian camels to easily approach and leave the road surface. The gentle slopes also improve safety by providing better visibility of livestock to drivers. Livestock herders that want their livestock to traverse the OT-GS Road can use these livestock crossings by guiding their animals to these locations. These at-grade livestock crossings are unlikely to be either an attractant or a deterrent to wildlife on OT roads. The researchers do not expect that the livestock crossings will be used heavily by livestock. The researchers expect that livestock presence and scent (urine, feces) will not be heavily concentrated at livestock crossings. However, should livestock spend substantial time at the livestock crossings, and should they urinate and defecate in high volume, then desert ungulates may avoid the immediate location of the livestock crossings.

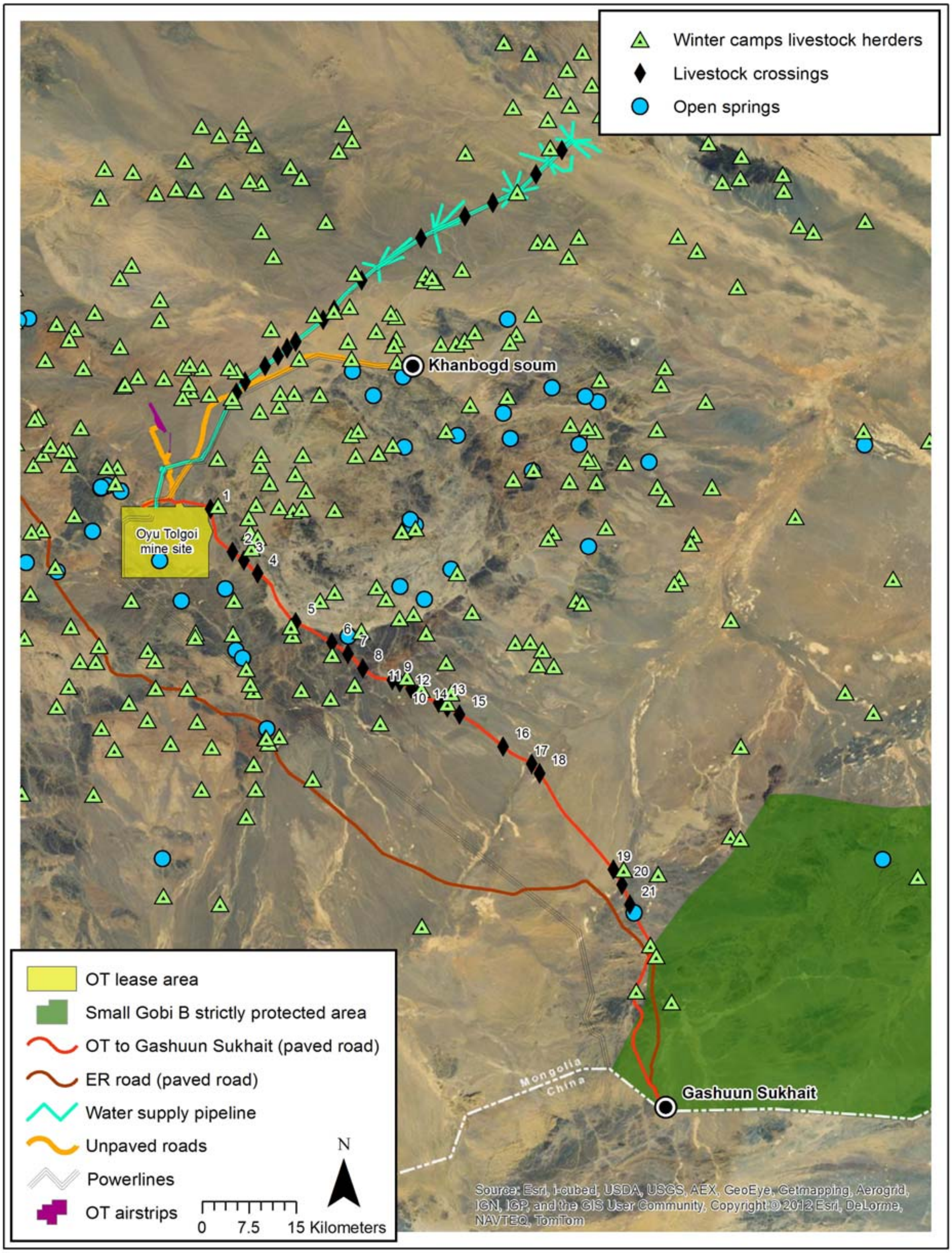

Figure 5: Livestock crossings, (winter camp) locations of livestock herders, springs.

Figure 6: Livestock crossing along OT-GS Road, Gobi, Ömnögovi, Mongolia (© Marcel Huijser). A livestock crossing consists of a very gradual slope on both sides of the road (perhaps about 10-20 m wide (road length) at selected locations. These types of livestock crossings were requested by nomadic livestock herders who believe that domesticated Bactrian camels may have trouble crossing the standard slope associated with the road bed.

3.3 Natural Habitats and the Gobi Environment

The Gobi covers roughly 300,000 km^2 of desert steppe and desert in southern Mongolia. The OT study area is located in the southeast portion of the Gobi in the southeastern section of the Omnogovi aimag near the soem of Khanbogd. The continental climate of the Gobi has resulted in extensive grass and shrub steppe rangeland. Key environmental factors that influence stability and resilience of grazing ecosystems are the amount and timing of precipitation, temperature, soils, and the intensity of livestock grazing activity. Roughly two-thirds of all precipitation and almost all vegetative growth occur between May and September. Annual precipitation increases from approximately 100 mm in the southern desert steppe to 300 mm in the northern steppe (Nandintsetseg & Shinoda 2011).

The composition of rangeland vegetation and the temporal and spatial distribution of annual forage are important factors regulating not only livestock production in the Gobi but also wildlife distribution. Extreme and often unpredictable fluctuations in forage quantity and quality between seasons and years and between local geographic areas is characteristic of the Gobi. The plant community of the desert areas is dominated by a mix of plant species associated with semi-desert steppe and desert steppe regions such as saxaul (*Haloxylon ammodendron*) and *Anabasis brevifolia*. Members of the Asteraceae family, such as the genera *Artemesia* and *Ajania*, and the

Poaceae family, including the genera *Stipa* and *Ptilagrostis*, dominate the steppe areas (Hilbig 1995). There is slight topographic relief, and few small mountain ranges are found in the southeastern Gobi area. Elevations range from 750 to 1900 m. The region can be characterized as a largely flat landscape with few distinct topographic features.

The Gobi is a base for pastoral livestock production. The human population lives primarily in the soum center of Khanbogd with the rest of the human population being widely dispersed throughout the southeastern Gobi region. Major large domestic herbivores are sheep, goats, horses, cattle and camels. Water is a critical resource for humans, livestock and wildlife in the region. Surface water is available in the form of wells, springs, lakes, seeps or creeks and is highly variable and influenced by local rainfall patterns. The groundwater table is relatively high, being accessible at 0.5 m below the surface in dry riverbeds. Well locations are generally known at the local level, but a Gobi-wide database is not currently available.

3.4 **Species in Study Area**

The number of species endemic to Mongolia is low compared with most countries but the unique eco-regions found in the country coupled with relatively low human activity have resulted in an important assemblage of fauna and flora. According to Mongolia’s Fourth National Report on implementation of the Convention on Biological Diversity, the country is home to nearly 3,000 species of vascular plants, 76 species of fish, six species of amphibians, 21 species of reptiles, 472 species of birds, and 138 species of mammals (MNET 2009). Information on species of concern in Mongolia has improved dramatically with the publication of the Mongolian Red List of Mammals (Clark et al. 2006). Until now, overexploitation for fur and meat has been the major cause of population decline for most Mongolian large mammals.

3.4.1 Native Large Mammal Species

Priority biodiversity features were identified to assess the impact of the OT-GS Road upgrade and direct the mitigation measures. A total of 11 priority biodiversity features are known or expected to occur in the sphere of influence or estimated impact zone of the OT-GS Road (TBC & FFI 2011). This includes 4 desert ungulates: khulan, black-tailed gazelle, argali, and Mongolian gazelle. Three of the open habitat ungulates (khulan, black-tailed gazelle, and argali) are of particular concern, because the area comprises Critical Habitat for their survival (TBC & FFI 2011). While Siberian ibex (*Capra sibirica*) has been observed south and east of the OT mine site, Siberian ibex is not considered a focal species for this project.

3.4.2 Focal Species

Mongolia’s steppe and Gobi desert ecosystems are home to one of the largest populations of wild open plains ungulates in the world and is the last major refuge for the endangered khulan and several other species (Clark et al. 2006, Yang 2007). However, many of the open plains ungulate populations in southern Mongolia are currently facing potentially severe habitat fragmentation and loss (Lkhagvasuren 2007, Kaczensky et al. 2011, Ito et al. 2013). Anthropogenic linear features such as roads and railways appear to be primarily responsible for fragmenting the habitat of the nomadic and migratory ungulates throughout Mongolia and interfering with their long distance movements (Ito et al. 2013, Kaczensky et al. 2011). Given the variable climatic and rangeland conditions in the southern Gobi desert, these ungulates require unimpeded access to the vast ranges they utilize year-round. Siberian ibex (*Capra sibirica*) has been observed south of the OT mine site, but Siberian ibex is not considered a focal species for this project.

The OT-GS Road is expected to impact Critical Habitat of four focal species of open plains ungulates. Below we describe these four focal species, their distribution, estimated population size and conservation status.

Khulan or Asiatic Wild Ass (*Equus hemionus*)

Khulan are found in desert steppe and typically are grazers. In Mongolia they eat grasses such as *Stipa glareosa, Agropyron cristatum* and *Achnatherum* spp. throughout the year. They can be found in rocky or sandy areas associated with *Artemisia*, grasses, *Anabasis* spp., Russian thistle (*Salsola* spp.), saxaul and pea shrubs (*Caragana* spp.).

The population of khulan in Mongolia is considered to be the largest in the world (Reading et al. 2001). The core of the Mongolian khulan range is found in the southeastern Gobi, in Omnigovi and Dornogovi aimags, and in the southeast corner of the Dundgovi aimag (Reading et al. 2001, Kaczensky et al. 2006). Recent population estimates vary widely and are plagued by wide confidence limits; they have typically lacked statistical rigor for reliable demographic information (Kaczensky et al. 2006). The current Mongolian population estimate is between 20,000 to possibly more than 50,000 individuals, with a few thousand more in neighboring China (Yang 2007; Lkhagvasuren et al. 2011, Dordjerem S, personal communication). However, because of a border fence between Mongolia and China the populations in the two countries are currently physically separated.

Khulan populations have been fully protected in Mongolia since the 1950s (Clark et al. 2006) and large parts of its habitat are under formal protection (Kaczensky et al. 2011). Of the 11 priority biodiversity features associated with the OT mine site, khulan is the only species with Tier 1 Critical Habitat affected by the site's sphere of influence (TBC & FFI 2011). Khulan are listed as "endangered" on the IUCN Red List (IUCN 2013) and National Red List of Mongolia (Clark et al., 2006).

The OT mine site and OT-GS Road are situated in the middle of the largest remaining population of khulan in the world, thus representing a critically important part of the remaining global range and the species and that of other globally threatened ungulate species. Khulan conservation and management efforts need to occur at a landscape scale. Radio-collared animals have ranged over 90,000 km^2, traveling through and between several protected areas (Kaczensky et al. 2011). The khulan's extensive movements and vast year-round range make localized population counts relatively meaningless.

Measuring and assessing the impacts of the OT mine site and its operations on the khulan population will require sound data on their numbers and distribution. For that reason, OT biologists and their aerial survey consultants have conducted two ground surveys and will conduct an aerial survey over 150,000 km^2 in May 2013. The latter will provide the Mongolia Ministry of Nature and Environment and OT managers more reliable estimates of population size and distribution in southern Mongolia and the OT mine site environs (Dorjdorem S., OT biodiversity supervisor, personal communication).

Black-tailed gazelle or goitered gazelle (*Gazella subgutturosa*)

Black-tailed gazelles have a vast distribution encompassing Mongolia and northwestern China to Israel and the Arabian Peninsula. They inhabit semi-deserts, steppes, valleys, mountain slopes and alpine grasslands and are semi-nomadic, undertaking limited but regular seasonal movements. In spring, autumn and dry summers, gazelles move over short distances in search of water and pasture. Herds cover 10-30 km per day in the winter, with these distances reduced nearly tenfold in summer (Mallon & Kingswood 2001). Normally, if the habitat is suitable, they are widely dispersed.

In Mongolia, recent estimates of the population suggest about 53,000 - 60,000 animals at the beginning of the 1990s (Mallon & Kingswood 2001). According to the IUCN Red List, Mongolia is thought to contain the largest remaining population of the species, holding an estimated 40-50% of the global population. However, poaching in the last 2-3 years may have reduced this population, and this possible decline is suspected to continue. According to Reading et al. (1999) about 100,000 gazelles were estimated during the mid '90s and numbers have been declining since.

The sphere of influence of the OT mine site effects Tier 2 Critical Habitat of the black-tailed gazelle (TBC & FFI 2011). They are listed as “vulnerable” on the IUCN Red List and National Red List of Mongolia. There is limited information on the estimated numbers and distribution of black-tailed gazelles in the project area and southeastern Gobi.

Argali (*Ovis ammon*)

Argali are distributed widely, but patchily across a large portion of Mongolia. Historically, argali resided in disjunct populations across all but eastern Mongolia, in areas with rolling hills, mountains, rocky outcrops, canyons, and plateaus.

Argali appear to be expanding their distribution in eastern Mongolia, but contracting and becoming even more fragmented in western Mongolia. Large areas formerly occupied by argali in western Mongolia now lack the species (Harris & Reading 2008). No rigorous population estimates exist for Mongolia. The Mongolian Academy of Sciences has conducted a few nation-wide surveys; however, the methods used do not permit accurate population estimation (Lkhagvasuren 2010).

The main threat facing argali in Mongolia is poaching, for subsistence and increasingly for their horns, which are being used as substitute horn in traditional Chinese medicine (Lkhagvasuren 2010). Also important are the impacts from local, nomadic pastoralists who displace argali, whose livestock feed on the same forage as argali, and whose dogs chase and even kill argali.

The sphere of influence of the OT mine site affects Tier 2 Critical Habitat of Argali (TBC & FFI 2011). They are listed as “near threatened” on the IUCN Red List and “endangered” on the National Red List of Mongolia. There is limited information on the estimated numbers and distribution of Argali in the OT mine site area and southeastern Gobi.

Mongolian gazelle (*Procapra gutturosa*)

Mongolian gazelles were formerly distributed throughout steppes and semi-deserts across Mongolia from west to east. Until about 1950, Mongolian gazelles were distributed over almost all the steppe and semi desert zones of Mongolia within a range of 780,000 km^2, and they numbered 1,500,000 (Jiang et al. 1998). Mongolian gazelles were once common in the west of the country, but by the end of the 1970s, this species had virtually disappeared from western Mongolia and only one isolated population remains on the Khomin Tal Steppe in Zavhan Aimag province, to the southeast of Har-Nuur Lake (Mallon & Kingswood 2001). Between the 1940s and the 1960s, its range was reduced by 70% (Lkhagvasuren & Millner-Gulland 1997). Large concentrations still occur in the steppes of eastern Mongolia, but only small, scattered populations remain in central and southern Mongolia.

Suitable habitat of Mongolian gazelle is the *Stipa* spp. steppe with low mountains and hills. The species is nomadic, moving from place to place depending on the availability of water and forage. It is considered an indicator of *Stipa* spp. steppe ecosystem health in eastern Mongolia (Lkhagvasuren 2000).

The main causes of population decline are intensively developed livestock husbandry and overgrazed pastureland. Poaching and over-hunting have taken their toll on the population as well (Reading et al. 1998). The Ulaanbaatar-Beijing Railway or Trans-Mongolian Railroad bisects the habitat of Mongolian gazelle and is fenced on both sides to prevent livestock from entering the track. The railroad has been shown to be a barrier to Mongolian gazelle movements and is hindering re-colonization of former range to the west (Ito et al. 2005, Ito et al. 2013).

The unit of analysis for the Mongolian gazelle does not qualify as critical habitat (TBC & FFI 2011). They are listed as “least concern” on the IUCN Red List and “endangered” on the National Red List of Mongolia. Mongolian gazelle have only been observed north of the OT mine site, otherwise there have been very few observations of the species (Personal communication, Purevsuren Tsolmonjav, OT).

Summary:

- The region that the OT-GS Road traverses is an open area with low human population densities and widely roaming wildlife.
- When considering fragmentation impacts to the regional fauna, four focal species are identified; the khulan, the black-tailed or goitered gazelle, the argali and the Mongolian gazelle.

4 CHARACTERISTICS OF THE FOCAL SPECIES IN RELATION TO ROADS AND SAFE CROSSING OPPORTUNITIES

4.1 Threats to Long-term Persistence

Khulan suffers mostly from intentional mortality, habitat degradation and habitat fragmentation. Black-tailed gazelles suffer mostly from intentional mortality and habitat degradation. Mongolian gazelle suffer mostly from intentional mortality and habitat fragmentation, and Argali suffer from intentional mortality, habitat degradation and competition with livestock.

The conservation status of the four target species suggest that, at an international level, it is extremely important to avoid, minimize or compensate any potential negative effects on khulan, black-tailed gazelle, and argali, and (to a lesser extent) Mongolian gazelle. At a national level the concerns are greatest for khulan, Mongolian gazelle, and argali, and slightly less for black-tailed gazelle. Interestingly, intentional mortality (i.e. legal and illegal hunting) is the most important threat for all four species in Mongolia, suggesting that it is critical to the long term survival of these species in Mongolia that poaching (and thus travel of humans into and out of the habitat of the species) be significantly reduced or controlled (cf. TBC & FFI 2012). Unfortunately, the addition of any road increases access to the areas surrounding the roads, and therefore increases the number of people leaving and accessing the road at will.

Summary:

- Substantial measures to avoid, minimize or compensate negative effects of the three OT Roads on the four focal species are warranted.
- Controlling, reducing or eliminating poaching is critical to the long-term survival of the four species.
- Road mitigation is just one part of a comprehensive mitigation solution. Poaching may have greater negative effects on long-term persistence of the species than population (genetic) isolation from fragmentation effects of roads (Forman et al. 2003).

4.2 Large Home Ranges, Nomadic Movements and Long Movement Distances

Khulan have home ranges on average of more than 30,000 km^2 and can range from 11,400-69,988 km^2 in SE Gobi (Kaczensky et al. 2011)). Black-tailed gazelle are capable of migrating distances of 100-250 km (CMS/UNEP 2008), while the home range of Mongolian gazelles can range from 14,000-32,000 km^2 annually (Olson et al. 2010). All four species have large home ranges or long distances over which they migrate or roam. These can be referred to as nomadic movements as they are not necessarily predictable in space or time (Olson et al. 2010, IUCN 2013, Ito et al. 2013). Argali home ranges are much smaller than those of khulan and the gazelles; they average 57 km^2 and can range from 30-80 km^2 (Reading et al. 2005). Argali may not have pronounced migration or nomadic movements like the other three ungulates.

Precipitation may vary spatially and temporally in the Gobi, resulting in ungulate movements that are perhaps more nomadic, rather than predictable seasonal migrations in distinct corridors. This makes it harder to predict where and when desert ungulates may attempt to cross the road. However, the large home ranges, and long movement distances or nomadic movements do indicate that khulan, black-tailed gazelle and Mongolian gazelle have a pronounced need to cross the roads and other barriers in the landscape for their long term survival. Since habitat fragmentation generally has a negative effect on all species, reducing the barrier effect of the road and traffic for argali is also recommended. However, since argali are less far ranging and likely not be truly migratory or nomadic in this area, the negative effects of an unmitigated road may not be as apparent compared to khulan, black-tailed gazelle and Mongolian gazelle. However, if the population of argali in the area is small, and if the project roads split this population into smaller subpopulations, argali may still eventually disappear locally because of their small and isolated population structure.

In conclusion, providing for effective safe crossing opportunities is extremely important for khulan, black-tailed gazelle and Mongolian gazelle. If roads and railroads are, or become, substantial barriers in the Gobi, the size of the habitat patches within the road and railroad network are unlikely to be sufficient for the long term survival of individuals and also the species. In addition, the migratory or nomadic movements can also be considered characteristic for the ecosystem; losing or diminishing these phenomena can be viewed as a loss of ecological integrity for the ecosystem. Effective safe crossing opportunities can address the barrier effects of roads, railroads, and traffic. The locations for safe crossing opportunities are not necessarily obvious; however, these species appear to be mostly nomadic without a clear spatial or temporal pattern for their movements. Therefore, regular spacing of safe crossing opportunities along the length of the OT-GS Road may provide a reasonable approach to mitigation. However, if evidence is gathered that one or more of the focal ungulate species have crossed the road, or are seen regularly in close proximity to the road at particular locations, it would be strategic to locate safe crossing opportunities at such locations (particularly if there is an obvious topographic or biological reason why such locations may be more suitable). Since the khulan, black-tailed gazelle and Mongolian gazelle have very large home ranges and do not necessarily travel the same routes with regularity, these animals may not have the prospect to become familiar with the location of safe crossing opportunities. If they do encounter safe crossing sites, they may not have much opportunity to learn that it is safe to approach the crossing structures and use them to get to the other side of the road. This has important consequences, as there is often a learning curve for many species; the use of the structures may be relatively low just after construction, the use may climb for the next 4-6 years or longer (since the species may not encounter the structures on a regular basis), and then level off (Clevenger et al. 2009). An increase in traffic volume may also affect at grade crossings or crossings through underpasses or overpasses by wildlife. In unmitigated sections (no wildlife fencing, no visual barriers, no safe crossing opportunities) the barrier effect of the road and traffic will likely increase. In mitigated road sections (wildlife fence, visual barriers, safe crossing opportunities) the effect may be less pronounced.

Summary

- Effective safe crossing opportunities that reduce or eliminate the barrier effect of the roads and railroads are essential to the long term survival of khulan, black-tailed gazelle, and Mongolian gazelle. The immediate negative effect of the barrier effect of roads and traffic may be less obvious for argali, but this species may still disappear if their population size is low and if the roads result in a small and isolated population structure.
- The movements of khulan, black-tailed gazelle, and Mongolian gazelle are not necessarily predictable in space or time. This suggests that safe crossing opportunities should be spaced at relatively short intervals along the project roads for these species (cf. TBC & FFI 2012). Alternatively, these species must be encouraged to move in the direction of the safe crossing opportunities from a long distance (see later). Argali movements may be more predictable in space, and potentially also in time. This makes it easier to select locations for safe crossing opportunities for argali than for khulan, black-tailed gazelle and Mongolian gazelle.
- Because of their large home ranges and migratory or even nomadic movements, khulan, black-tailed gazelle and Mongolian gazelle do not necessarily have the opportunity to learn about the location of the crossing structures and learn that it is safe to use them. This suggests that the type and dimensions of the crossing structures should be as inviting as possible. Argali likely have more opportunity for exposure to the same crossing structures and may be more likely to learn that it is safe to use them.

4.3 Open Landscapes and Long View Distances

In the Gobi and the areas surrounding the roads associated with the OT project, the khulan, black-tailed gazelle, and argali are considered characteristic species. The Mongolian gazelle is considered a species characteristic for the Daurian steppe eco-region and is only observed infrequently in the project area. All four species are characteristic of open areas: grasslands or sparsely vegetated desert. Most of the “central valley” along the OT-GS Road, where most of the khulan and black-tailed gazelle have been observed (Figure 7), is extremely flat with sparse vegetation allowing for very long viewing distances. It should be noted that the wildlife surveys conducted up to this time are biased to these areas of the project area, and that long viewing distances aid in the detection of ungulates, so it is possible that these may not be the most important areas for the species (particularly when considering their nomadism and thus areas identified as important at this point in time, may not be as important in coming years). Argali generally stay close to rocky areas that serve as escape terrain from predators. This suggests that the khulan, black-tailed gazelle, and Mongolian gazelle require large and wide structures with a very gradual approach (slope at or near 0°). Argali may be more accepting of smaller structures and shorter view distances.

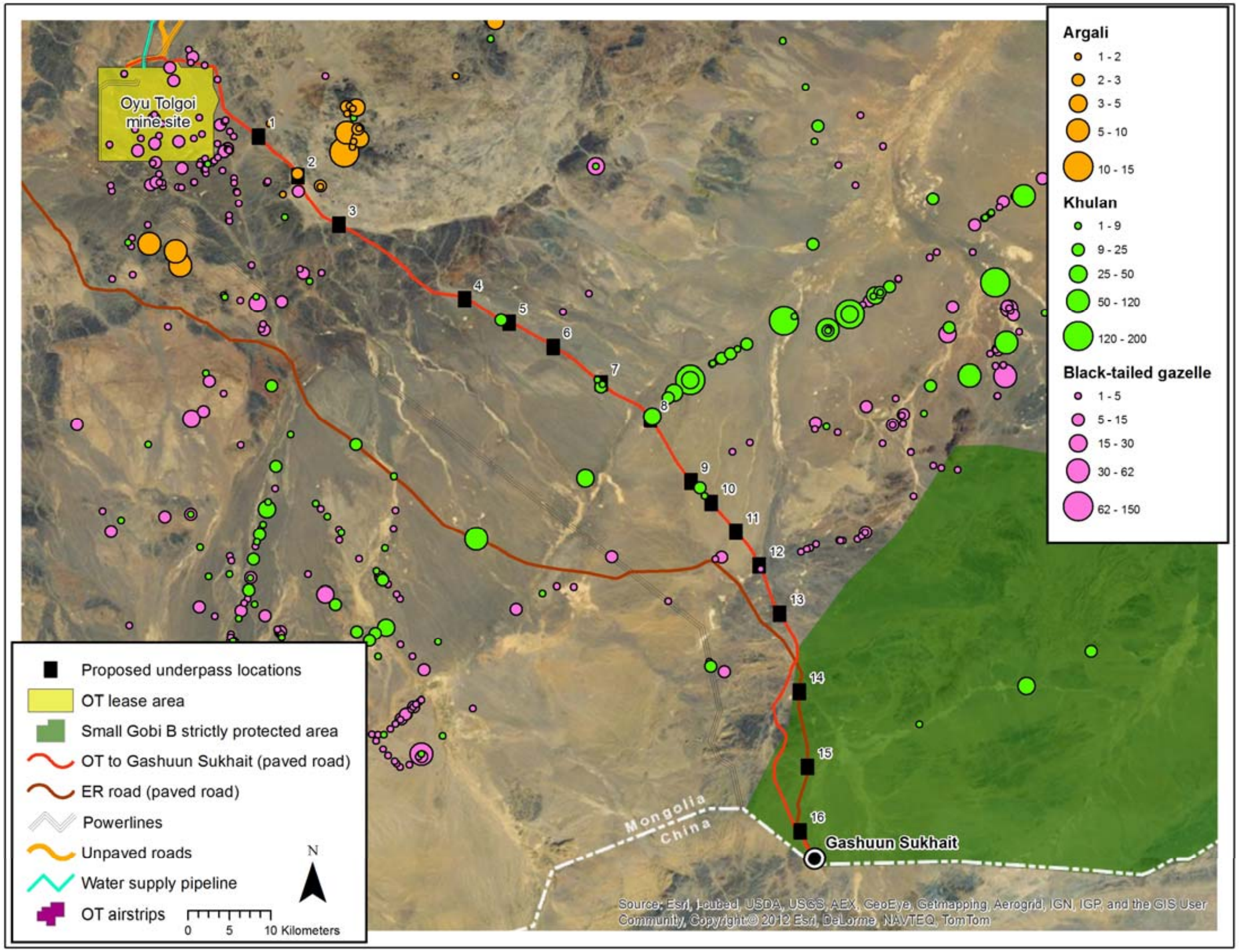

Figure 7: Observations of Wildlife Species of Interest. Note that the "proposed" underpass locations are based on OT data. The current document contains different recommendations (see Chapter 6 and 7).

The concept that species that live in open landscapes with flat terrain require large and wide structures with a very gradual approach (slope near 0°), is supported by the following examples:

- The Qinghai–Tibet railway railroad bisects migration paths of the Tibetan antelope. There are 143 underpasses that are more than 100 m wide but only a few of those are used by the Tibetan antelope (Yang & Xia 2008). The adjacent highway is usually only crossed when there is a lull in traffic (Yang & Xia 2008). The structure over which 90-98% of Tibetan antelope cross is a large overspan bridge across a lower lying area (Xia et al. 2007; Personal communication Yun Wang, China Academy of Transportation Sciences). The structure is about 214 m wide (railroad length) and 7.3 m high (Personal communication Yun Wang, China Academy of Transportation Sciences). Structures that were 5-10 m wide (railroad length) and 1-2 m high were not or extremely rarely used by Tibetan antelope (Xia et al. 2007). The removal of construction debris at the underpasses appears to be important for successful crossings (Xia et al. 2007).
- The Trans-Mongolian railroad is a very substantial barrier to Mongolian gazelles and khulan (Ito et al. 2008; Kaczensky et al. 2011; Ito et al. 2013). The livestock fence is difficult to cross for these species, and substantial numbers of Mongolian gazelles get entangled in the livestock fence and die (Ito et al. 2008; Olson 2012). Others are directly hit by trains (Olson 2012). There are culverts and underpasses along the Trans-Mongolian railroad to allow for water flow and livestock movements. Some of the culverts are behind the livestock fence resulting in reduced access for wildlife, while others have the livestock fence tied in to the sidewalls of the structure or have the fence continue above the structure (Figure 8 and Figure 9). However, the structures and configurations present along the Trans-Mongolian railroad do not appear to allow for much wildlife movement (Olson 2012). The distribution of the carcasses suggests that the Mongolian gazelle are not attracted to the structures when crossing the railroad. Some livestock herders have seen Mongolian gazelle move through some structures, but they have never seen the structures used by khulan or argali.
- In North America, Sawyer and Rudd (2005) and Dodd et al. (2011) recommended large open structures, particularly overspan bridges and overpasses for pronghorn (*Antilocapra americana*). Pronghorn are not nomadic; they are migratory species and likely less sensitive to human disturbance than what has been reported for khulan or Mongolian gazelles (Kaczensky et al. 2006, Ito et al. 2008). The structures need to be as "as open and wide as possible, with attention paid to avoiding obstructed line-of-sight views through or across the structures or any restrictions to mobility" (Dodd et al. 2011). In Wyoming, pronghorn primarily use a 46 m wide overpass rather than 21 m wide (road length) and 4.6 m high underpasses (width of the area that is not sloped was about 6.1 m and height was about 3.7 m) (H. Sawyer, personal communication). Underpasses are also present in this road section, but they receive relatively little use by pronghorn; more than 90% of the pronghorn that cross are using the overpass (Jackson Hole News & Guide, 2012; interpretation of news release WYDOT, 2013). The overpass has earthen berms on

top to block the view of traffic. A 2.4 m tall wildlife fence ties the crossing structures together and helps funnel pronghorn to the crossing structures. The soil on the overpass has been planted with native grasses and shrubs and matches the vegetation in the surroundings. While pronghorn are not really known for using underpasses, one underpass was used by pronghorn (Plumb et al. 2003). This underpass was 6.1 m wide (road length), 3.0-3.3 m high and 18.3 m long (road width) (Gordon & Anderson 2004).

- In Israel, large underpasses (viaducts) have been used by some individuals of both mountain gazelle (*Gazella gazelle*) and Dorcas gazelle (*Gazella dorcas*). A wide overpass (150 m wide) was used by a few individual gazelles, and a narrower overpass (50 m wide) was potentially used by one individual gazelle (Personal communication, Tamar Achiron, independent consultant at Ron Frumkin and Tamar Achiron-Frumkin).
- In the northern Rocky Mountains, Clevenger and Huijser (2011) consider landscape bridges, wildlife overpasses or viaducts (long bridges) to be most suitable for bighorn sheep (*Ovis canadensis*), while a large mammal underpass may be suitable under some circumstances (Clevenger & Huijser 2011). Dimensions for a large mammal underpass for bighorn sheep are at least 12 m wide (road length) and 4.5 m high. In more open desert landscapes in Arizona, overpasses (about 15-30 m wide (road length)) were more frequently used by desert bighorn sheep (*Ovis canadensis nelsoni*) than 51-116 m wide (road length) and 18-25 m high underpasses and viaducts (Bristow & Crabb 2008, Gagnon et al. 2012). The desert bighorn sheep appear to mostly cross the road at ridges rather than gullies, perhaps explaining why relatively narrow overpasses are used more frequently than the wider viaducts.

Summary

- Ungulates of open landscapes seem to require large and open structures with long, line-of-sight viewing distances through or across the crossing structures.
- The culverts and underpasses along the Trans-Mongolian railroad are rarely used by Mongolian gazelle; khulan and argali use them even less often or not at all.
- Landscape bridges (buried road over long distances) and viaducts (elevated road over long distances) with very gradual approaches and long sight distances through or across the structures are likely the most successful crossing structures for khulan, black-tailed gazelle and Mongolian gazelle.
- Argali may be similar to desert bighorn sheep and may require landscape bridges or overpasses (50-70 m wide (road length)). Viaducts (200 m wide) and underpasses (50 m wide (road length) or 12 m wide (road length)) may be (much) less suitable for argali. Since argali are twice as heavy as desert bighorn sheep, argali may require wider overpasses than the 15-30 m wide overpasses successfully used by desert bighorn sheep in Arizona. This suggests that an overpass width of 30-60 m (road length) is perhaps more suitable for this large wild sheep species than an overpass that is only 15-30 m wide (road length).

Figure 8: Underpasses for livestock and/or water along Trans-Mongolian Railway, between Choyr and Nalayh, Töv / Govisümber, Mongolia (© Marcel Huijser). The railroad and the livestock fence are a very substantial barrier to the movements of khulan and Mongolian gazelle. The underpasses, bridges and culverts are not or barely used by these species as they are likely to small (not wide enough, not high enough).

Figure 9: Underpasses for livestock and/or water along Trans-Mongolian Railway, between Choyr and Nalayh, Töv / Govisümber, Mongolia (© Marcel Huijser). The railroad and the livestock fence are a substantial barrier to the movements of khulan and Mongolian gazelle. The underpasses, bridges and culverts are not or barely used by these species as they are likely to small (not wide enough, not high enough).

4.4 Strong Road Avoidance

As a result of legal and illegal hunting and other human caused disturbance, the four ungulate focal species are likely to keep their distance from roads, especially if traffic or other human related disturbance is present. Tibetan antelope (*Pantholops hodgsoni*), Tibetan gazelle (*Procapra picticaudata*) and Kiang (*Equus kiang*) all had significantly lower densities up to 500 m away from the Qinghai-Tibetan highway compared to a zone further away from the road (1001-3000 m distance) (Yin et al. 2007). Lian and others (2012) reported avoidance distances for wild yak (*Bos grunniens*) (999 m ± 304 m), Kiang (568 m ± 83 m), Tibetan antelope (286 m ± 27 m), and Tibetan gazelle (177 m ± 14 m). Tibetan antelope were more alert and did not forage as much closer to roads, indicating awareness of increased risk or danger (Lian et al. 2011). High traffic volume has also been found to keep Przewalski's gazelle (*Procapra przewalskii*) away from roads (Li 2009). A two lane highway with about 10,000 vehicles per day in North America was almost an absolute barrier to the movements of pronghorn (Dodd et al. 2011). Bighorn sheep in North America also keep their distance from roads and traffic avoiding an area within 350-500 m from roads (Papouchis et al. 2001). Some literature indicates that traffic volumes of more than 2,000 vehicles/day may have some barrier effect (Sawyer & Rudd 2005; Clevenger & Huijser 2011) and volumes of more than 4,000 vehicles/day may create strong barriers to wildlife movements in North America (Mueller & Berthoud 1997). The focal species are more sensitive to traffic. Based on fleeing distances and speed, TBC and FFI (2011) estimate a serious barrier effect for khulan at 400 vehicles/day and a complete ecological barrier at 1,000 vehicles/day.

This suggests that minimizing visual and other human related disturbance is required in the vicinity of safe crossing opportunities. At safe crossing opportunities, the minimum distance to seeing traffic may be perhaps 200-300 m for gazelle species, 300-500 m for argali sheep, and 500-600 m for khulan. At narrow crossing structures this suggests having continuous visual barriers extending for 200-300 m of road length from the crossing structures for gazelle, 300 - 500 m for argali sheep, and perhaps 500-600 m for khulan. Since a landscape bridge is very wide (e.g. 1000 m road length) the visual barriers may not have to extend as far from the structure, at least not when the animals are primarily expected to use the center of the structure to cross.

Summary

- If the four ungulate species avoid areas close to the road because of traffic, people and other human caused disturbance, including poaching, even suitable structures may not be used by the target species to a level that is desirable. Therefore, it is essential to reduce or eliminate negative effects emerging from the road such as poaching, vehicles leaving the road, and seeing vehicles and other human activities associated with the road corridor at or near the safe crossing opportunities.
- Barriers that discourage vehicles and people from leaving or accessing the road are suggested in the immediate vicinity of safe crossing opportunities.
- Continuous barriers that discourage vehicles and people from leaving or accessing the road are suggested in areas that have a concentration of safe crossing opportunities (e.g. less than 2 km apart).
- It is advised that visual barriers be constructed to obstruct a direct view of traffic, including large trucks that may travel the road frequently, by wildlife approaching structures (Figure 10, Figure 11).
- The suggested extent of visual barriers should be at least 200-300 m of road length on both sides of the crossing structure for gazelle, 300 -500 m for argali sheep, and perhaps 500-600 m for khulan. If more than one species is selected as a target species for a particular structure at a particular location, use the distance suggested for the most sensitive species (i.e. the longer distance).

Figure 10: Overspan bridge with visual barriers, Rijksstraatweg Utrechtsestraatweg N225 just east of Elst, The Netherlands (© Marcel Huijser).

Figure 11: Visual barrier above wildlife underpass, near "Aardhuis" along N344, Amersfoortseweg, Hoog Soeren, The Netherlands (© Marcel Huijser). Note that the visual barrier along the project road in the Gobi should extend hundreds of meters beyond the actual crossing structure because of the open landscape, long view distances, and the road avoidance behavior of the desert ungulates.

Figure 12: Livestock fence along Trans-Mongolian Railway, between Choyr and Nalayh, Töv / Govisümber, Mongolia (© Marcel Huijser). The railroad and the livestock fence are a very substantial barrier to the movements of khulan and Mongolian gazelle. Mongolian gazelle regularly get entangled in the fence when trying to cross the fence and die (Olson 2012). Others are hit by the trains directly inside the fenced railroad corridor. The underpasses, bridges and culverts are not or barely used by these species as they are likely to small (not wide enough, not high enough).

5 THE TOOLBOX: WILDLIFE MITIGATION MEASURES APPROPRIATE FOR THE STUDY AREA

Numerous methods for mitigating the negative impacts of roadways on wildlife have been suggested, many have been implemented, and some have been evaluated for their effectiveness. There are relatively few mitigation measures, however, that reduce wildlife-vehicle collisions substantially and that also allow for safe road crossings by wildlife. In this chapter a range of different mitigation measures are described that may be appropriate for the study area. They include warning signs, traffic volume management, enforcement of traffic speed, education, traffic calming, fencing and wildlife crossing structures. General guidance on use, design, and location are included. Recommendations more specific to the OT-GS Road in regards to wildlife crossing structures are provided in Chapter 6.

5.1 Warning Signs

Static warning signs can be used to warn drivers of the potential for animals crossing the road. Hypothetically this makes the driver more aware, potentially resulting in a faster reaction speed of the driver, thereby reducing the likelihood of a collision should the driver encounter an animal on the road.

Warning signs in general (not necessarily specific to wildlife hazards) should improve driver expectancy (USDOT-FHWA 2009). That is, the hazards encountered by drivers after passing a warning sign should be similar every time; this allows drivers to create an expectation. Typically a driver will pass a wildlife crossing warning sign tens or hundreds of times without seeing any wildlife hazard. Thus, when the driver sees a wildlife crossing warning sign, they do not necessarily expect to actually encounter a wildlife hazard, they do not necessarily increase their awareness, and they are not necessarily more likely to avoid a collision.

Several studies of the effectiveness of animal crossing warning signs, including camel crossing warning signs in Saudi Arabia, have found no reduction in the number of collisions as a result of the presence of wildlife warning signs (Al-Ghamdi & AlGadhi 2004, Rogers 2004, Meyer 2006), though there may be some benefits in the first period after placing signs.

Some success in reducing wildlife-vehicle collisions has been seen with warning signs that have a higher likelihood of promoting driver expectancy, through being more precise in location or location and time. Examples include signs posted only during peak animal movement seasons and signs that are combined with sensors that detect animals when they approach the road (Huijser et al. 2009a).

Although likely ineffective at reducing collisions, animal crossing warning signs could be used to improve general public awareness of the wildlife problem on the OT-GS Road. Still, the research team does not encourage the use of standard or enhanced warning signs if the goal is to reduce wildlife-vehicle collisions. The research team does suggest the use of camel or general livestock warning signs at the designated livestock crossings if livestock indeed largely use these locations to cross the road (predictable locations).

Figure 13: Gazelle crossing warning sign on OT-GS Road (© Marcel Huijser).

Summary:

- Warning signs should be installed near livestock crossings if this is where most of the livestock crosses the road (guided by herders).
- Static wildlife warning signs are generally ineffective and should only be used as part of a public education program (see Section 5.9).

5.2 Reducing Vehicle Speeds with Posted Limits and Traffic Calming

The posted speed limit on the OT-GS road is 80 km/h. Although data are very scarce, this is slightly higher than the speed limit (76 km/h) at which substantially fewer wildlife-vehicle collisions occurred in Yellowstone National Park, Wyoming, USA (Gunther et al. 1998). Reducing the posted speed limit is a mitigation option, but is not strongly recommended. Reducing the posted speed limit excessively below the comfortable unhindered operating speed can set up a situation where motorists are encouraged to break the law, leading to speed dispersion (the spread of vehicle speeds). Instead of a tight distribution of speeds for vehicles on the road, two speed groups may result: one group of vehicles will travel at the posted speed limit and another will travel at the operating speed. It has been shown that speed dispersion increases crash rates even if average speeds decrease. Solomon (1964) and Cerrelli (1981) found that vehicles traveling close to the average speed had the lowest crash involvement rates. Crash involvement rate not only increased for faster vehicles, but also for slower vehicles. Garber and Gadiraju (1988) found a similar U-shaped relationship, where the further the posted speed was from the operating speed, the higher the crash rate for the roadway. Speed dispersion is particularly an issue on two-lane rural roads, because it increases the number of vehicles passing in unsafe situations. If the operating speed for the road is substantially higher than the posted speed limit, enforcement of the posted speed limit may not be very effective; drivers will travel at a speed consistent with the operating speed rather than the posted speed limit. Also, drivers who experience the low posted speed limit will perceive the potential enforcement of these speed limits as unjust. The ability to set and enforce posted speed limits depends on the legislation and guidelines from the Mongolian government. Enforcement may be through automated enforcement cameras or law enforcement personnel. Because OT company vehicles are equipped with GPS, an automated speed control system for these vehicles is already in place.

In the case of the OT-GS Road, the road is already designed and under construction. This limits the possibility to have a design for lower speed, which would result in a lower operating speed. While reducing vehicle speed does not necessarily reduce the barrier effect of the roadway to wildlife, lower vehicle speeds (e.g. 70 km/h or lower) may however reduce the likelihood of wildlife-vehicle collisions. It has been proven that reducing vehicle speed reduces the injury severity (to the human) when a crash occurs (National Research Council 1998). Results from studies on the effect of a reduced speed limit on the actual occurrence of crashes have been mixed. There seems to be an intuitive sense that lower speeds improve the chance of the driver to react. Several studies have reported success, but upon investigation of the data, results are undetermined. For example, in 1991, the speed limit was reduced from 90 km/h to 70 km/h to mitigate WVCs in Jasper National Park in Alberta, Canada, on the Yellowhead Highway. This roadway is a rural two-lane highway in a national park, with 3.7-m lane widths, and 3-m shoulders (Bertwistle 1999). Although claimed as a success, a deeper look at the data shows inconclusive results. Less than 20 percent of the vehicles obeyed the 70 km/h speed limit, and there appears to be no decrease in wildlife-vehicle collisions after the speed limit was reduced.

Another option to reducing vehicle speeds is to implement traffic calming measures. These may be installed on existing roads. Examples of traffic calming measures include transverse rumble strips and raised medians. Due to the cost of medians and potential annoyance of rumble strips to drivers, they are not recommended. Modifying the pavement markings within the same pavement width could be implemented. Godley et al. (2004) argued that by narrowing the perceived lane width with pavement markings the mental work load of the drive was increased. The increased mental work load would lead to slower speeds. A vehicle simulator study concluded that decreased lane widths showed a decrease of 2.2 km/h with the 2.5 meter lane widths. It was also seen that greater steering wheel deviations, movements of the steering wheel left and right, were noted with narrower lane widths, indicating that greater steering effort is required, resulting in greater driver alertness.

Summary:

- Reducing vehicle speeds through posted speed limits could be used to mitigate the direct wildlife mortality impact of the OT-GS Road, but is not recommended without also lowering the operating speed with traffic calming methods.
- If the posted speed limit is reduced below the typical operating speed, there must be an enforcement component.
- The existing program of monitoring OT vehicles for when they exceed the posted speed limit should continue.

5.3 Driver Awareness and Public Education

5.3.1 Overview

The OT roads project area and proposed wildlife mitigation measures could be well served with various driver education and public awareness efforts. Such outreach campaigns support other facets of the wildlife mitigation, such as creating off-road barriers, constructing wildlife crossing structures, and installing livestock crossings along the OT roads. Seeking to change driver behavior to discourage off-road use of vehicles, reduce wildlife-vehicle collisions and gain support for mitigating habitat fragmentation has been the purpose of many different driver education and awareness information and campaigns in North America (Huijser et al. 2007). Some of these strategies are also relevant to the OT roads. Given that both wildlife and domestic livestock issues need to be addressed as part of the net positive impact for the OT project, the researchers advise a combined driver education and public awareness campaign for both wildlife and livestock. In other areas, driver education programs have incorporated the use of media alerts, videos, brochures, billboards, posters, and bumper stickers. Often these activities work in concert with roadside messages at specific high-risk locations for collisions or in specific seasons of high wildlife migration or movement.

Many driver education programs seek to reduce human deaths and serious injuries on roadways through increasing motorists' awareness of the impacts, causes, and high risk locations of animal-vehicle collisions. There is little or no evidence that education programs actually achieve these goals and animal-vehicle collisions are currently not a major concern for the OT roads, especially when compared to habitat fragmentation and poaching. Nonetheless, an education program can help build public support for the implementation of measures that are more effective in reducing the negative impacts of the OT roads such as reducing off-road access for poachers and habitat fragmentation.

Driver education for the OT-GS Road can be more targeted than for a road with more general public use. A substantial portion of the traffic on the OT-GS Road is likely traffic associated with the mine site. A company-based information and education campaign can focus on truck drivers hauling concentrated ore to the Chinese border via the OT-GS Road. Public information and driver education efforts are thought to work best when conducted in concert with other wildlife mitigation techniques (Hardy et al. 2006).

One topic that can be addressed via outreach is making drivers aware that using vehicles off-road to approach, chase, harass or potentially poach wildlife is impermissible. If presented in a certain context, it may also be possible to present this behavior as culturally unacceptable. While off-road driving may currently be part of the driving culture in Mongolia, it destroys vegetation and causes soil compaction and erosion. This in turn affects primary production and the carrying capacity of the land for livestock and wild herbivores. Since livestock is extremely important to the culture in Mongolia, this may provide an opportunity to encourage drivers to stick to existing roads or two tracks rather than to drive anywhere.

In the U.S., public campaigns have been developed to try and reduce illegal off road vehicle use, primarily on public lands (Figure 14). A typical education campaign for off-road vehicles has a strong web-based presence, such as in Idaho (http://stayontrails.com/) or Arizona (http://azstateparks.com/ohv/index.html). An internet based campaign is likely not suitable for the general public in Mongolia though. Although physical barriers, such as ditches or berms, may preclude illegal use on many portions of the OT roads, some of the measures, or at least at some locations, may prove to not be an insurmountable barrier. A driver education and awareness campaign coupled with law enforcement can help to make departing established roads and two tracks in order to harass or poach wildlife less culturally acceptable.

Figure 14: Signage to make motorists aware that vehicles are not permitted off-road. (Source: www.roadtrafficsigns.com)

Several potential elements of public education and driver awareness campaigns are described below. Many of these focus on the wildlife-vehicle collisions. Some may not be suitable for implementing as part of the OT wildlife mitigation effort due to the very low number of reported wildlife-vehicle collisions, cultural differences, socio-economic issues, or some other reason.

However, we do recommend implementing some sort of driver awareness and public education effort that could be based on some of these elements. The exact implementation should be adjusted for the greatest possible success in the area around the OT-GS Road. Also, it should be expanded beyond wildlife-vehicle collisions to include habitat fragmentation issues and discouraging off-road vehicle use.

5.3.2 Campaign Types and Information

In North America, some road ecologists and safety engineers have conducted research related to motorist education efforts (Biggs et al. 2004). One study in Montana in association with a local outreach campaign found that survey respondents who had heard about wildlife-vehicle collisions after the outreach increased from 21 to 33 percent (Hardy 2006). However, there are no known studies that indicate that driver education or public information/awareness efforts have significantly decreased the incidence of wildlife-vehicle collisions (Knapp 2005). A recent 2 year study in Colorado, on a state-wide program that used warning signs in combination with reduced posted speed limits that were enforced in wildlife crossing zones, found that the project reduced wildlife-vehicle collisions by 9 percent (CDOT 2012) in the mitigated areas. The authors of the report stated there was no information on whether drivers slowed down, and, due to a lack of pre-construction data, no strong case can be made that the reduction in collisions was a result of the lower posted speed limits.

Perhaps one of the one of the most prolific of the education and awareness campaigns in the U.S. has been conducted by the state of Colorado. The “Colorado Wildlife on the Move” Campaign reached more than 3 million people through a variety of media outlets and included 58,000 driver safety tip sheets and 500 posters distributed in welcome centers, national parks, and commercial car rental offices. Information is available online at:

http://www.coloradodot.info/programs/environmental/wildlife/wildlifeonthemove

In Canada, the Parks Canada “Drivers for Wildlife” program in Jasper National Park combines public education, which includes bumper stickers and roadway billboards, with two digital signs that record speed and advise drivers to slow down in the high risk wildlife zone. The number of road-killed animals along park highways decreased by about 15 percent after the first 10 months of the public education and roadside sign program; however, the signs were given the most credit for the reduction of wildlife-vehicle collisions (Walker 2004).

These public education campaigns in the U.S. and Canada have provided numerous examples of educational materials, including the following bumper sticker (Figure 15), poster (Figure 16), and roadside billboard (Figure 17).

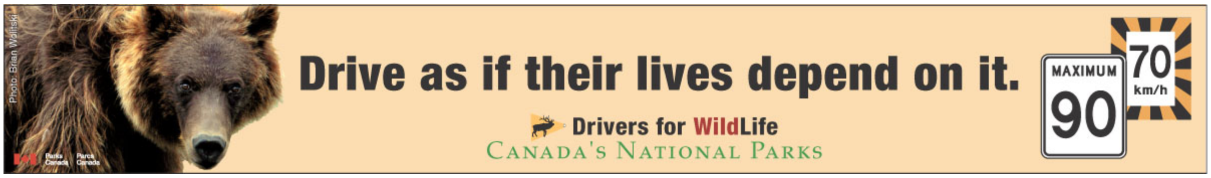

Figure 15: Example of Bumper Sticker for a Driver Awareness Campaign to Reduce WVCs in Jasper National Park, Canada (Source: Parks Canada).

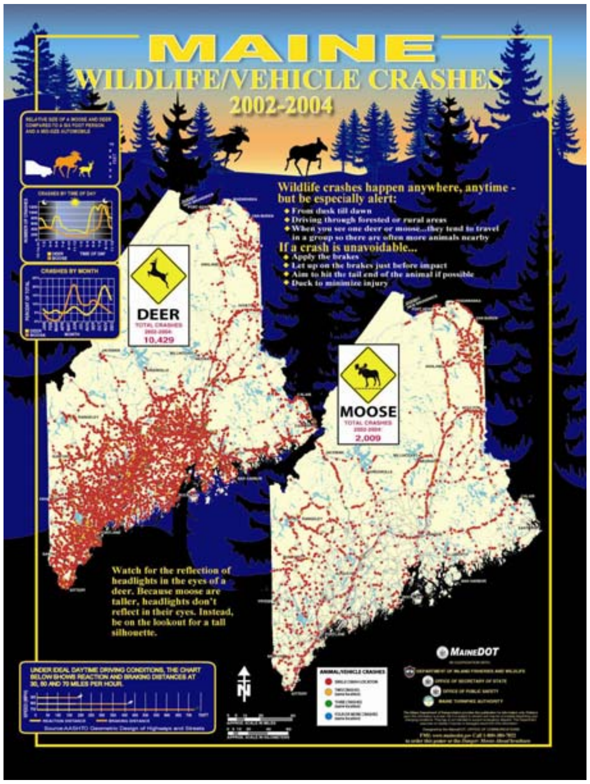

Figure 16: Poster produced by the Maine Department of Transportation (Source: Maine DOT).

Figure 17: A billboard alongside the highway in Jasper National Park, Canada (source: Parks Canada Agency).

5.3.3 Citizen Science Reporting Systems on the World Wide Web

One the most effective means of engaging the public on the issue of wildlife impacts of roads may be via a web-based reporting site. In North America, these citizen science sites let the public report on road-killed wildlife and wildlife seen alive on or near the road. In North America there are statewide websites in Idaho, California (http://www.wildlifecrossing.net/california/), Maine (http://www.wildlifecrossing.net/maine) and Massachusetts. In other locales, there are public websites dedicated to wildlife sightings on particular highways or highway segments. Examples of highway specific sites that have been developed are those for I-90 in Washington (Figure 18), http://i90wildlifewatch.org/, State Highway 75 in Idaho and Highway 3 in Alberta, http://www.rockies.ca/roadwatch/about.php.

Figure 18: Interstate Highway 90 Wildlife Watch billboard near Cle Elum, Washington, USA. Credit: Paula MacKay/WTI

Findings from the citizens science project on Highway 3 in Alberta indicate that citizens are reporting sites where successful wildlife crossings occur, but they don't necessarily correlate to locations with high numbers of roadkill (Lee et al. 2006). However, live sightings of wildlife by the public match those made by researchers in a controlled effort (Paul 2007). A report on the public wildlife reporting site for Idaho State Highway 75 drew the following related conclusions: citizens helped identify and strengthen the data for locations of high roadkill, live animals on or near the road, and potential successful crossings. As an added bonus, these efforts also helped to bring attention to species smaller than deer that are also killed by traffic (Kociolek et al. 2009). Note that web-based efforts may not be appropriate if the effort is targeted at the general population in the area (but perhaps it would be appropriate for OT personnel).

5.3.4 Summary

To increase awareness of the direct and indirect impacts of roads and traffic on wildlife, especially off road driving, poaching, and habitat fragmentation, OT may consider implementing a public awareness program and including more awareness in the OT employee information program for the three project roads. It may also be useful to make the existing wildlife reporting database (dead or alive, on or near the roads) fully accessible, with data entry options, to all OT employees who have access to computers and internet. Such a joint public-private campaign has the potential to appeal to the public and the OT workforce who are sympathetic to reducing the impacts of vehicles roads on both wildlife and livestock. The campaign can make a case for drivers to stay on the roads and two tracks and not harass or kill wildlife via off-road excursions with motor vehicles and not damage plants (food) for domesticated animals and wildlife in the process.

OT employees in company vehicles are unlikely to be a threat due to disciplinary controls by OT, but the public using the road are more likely to venture off-road when wildlife are observed. Making this behavior culturally unacceptable will be a challenge; it may take many years to create behavioral change. This is particularly true given that local herders use motorcycles and other vehicles off-road as standard practice to gain access to their herds of domesticated camels, goats, horses or other livestock. Note that information signs or wildlife warning signs cannot be expected to reduce the likelihood of wildlife-vehicle collisions. While wildlife-vehicle collisions do not appear to be a concern right now, traffic volume, vehicle speed, and an increase in night time traffic may eventually result in an increase in collisions.

5.3.5 Recommendations for Public and OT Employee Awareness and Education Campaign

As stated previously, the exact approaches cited above may not be appropriate for implementation in the OT-GS Road area. Some sort of driver awareness and public education effort is recommended that could include the elements described below.

Airport

Since most employees of OT and many visitors to the OT mine site arrive via air transportation, it would be advantageous to have an information kiosk in the arrival building at the airport to distribute information on the effects of roads and traffic on wildlife, information on mitigation measures implemented along the OT roads, and appropriate behavior of employees and visitors in relation to wildlife. This is an opportunity to introduce a captive audience to the topic of roads and wildlife immediately upon their arrival, before they get into any ground transportation vehicle. Educational materials may be developed over time to educate the public on the effectiveness of the wildlife crossings; for example, Parks Canada developed an outreach poster on the wildlife that uses its crossings (Figure 19).

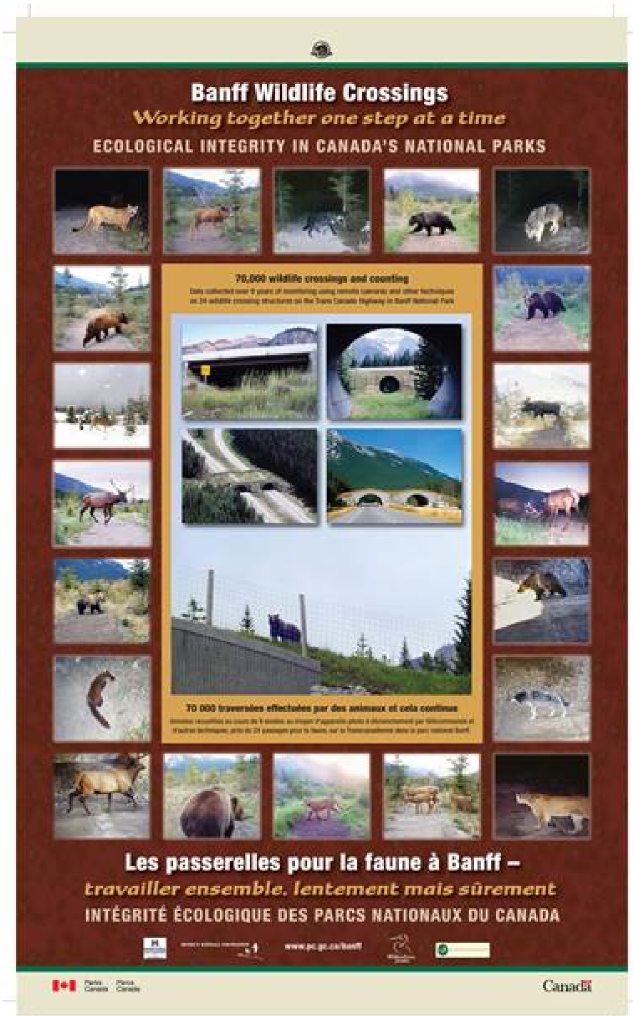

Figure 19: A poster produced by Parks Canada Agency demonstrating use of crossing structures by a variety of wildlife. (Source: PCA)

OT-GS Road at GS Border Crossing

For northbound traffic entering Mongolia at the border crossing with China, an information kiosk along the road or in the White Rock area could inform drivers of wildlife along the OT roads. Preferably all information would be in both Mongolian and Chinese (and potentially also English). However, because time is important to truck drivers, this is unlikely to be very effective for that user group. Roadside information signs at these locations would likely be mostly an indication of effort and not much more.

Signage Along the Road at Domestic Livestock Crossing Locations

Consider applying the same livestock warning signs at each livestock crossing. There are already warning signs present along the OT-GS Road; they feature the image of a Bactrian camel (Figure 20). A sign should be posted at each end of the each domestic stock crossing location to make drivers aware of the approaching site. It may be beneficial to stripe the highway at these sites so drivers know the extent of each crossing area. Also, it may prove necessary to have speeds reduced in these zones if herders feel that traffic is moving too fast and their livestock are alarmed or scattering due to vehicle noise and congestion. However, if livestock and livestock driven by herders actually cross the road randomly along the OT-GS Road rather than primarily at these sites, then the location of livestock on the road becomes far less predictable and the warning signs are very likely to be ineffective.

Figure 20: Bactrian camel warning sign along OT-GS Road (Photo: Rob Ament).

Information and Education for Roadway Departures by Vehicles

It is important to develop an information and education campaign to reduce off-road excursions by motorized vehicles from OT roads. This will be in support of the use of physical barriers, where appropriate. A suggested theme for the campaign could be “Off Road is Off Limits,” or something similar with terms more culturally appropriate to the Omnogovi aimag. The campaign will help develop a cultural intolerance for off road use that disturbs wildlife; enables potential poaching forays across the desert; and unnecessarily destroys soil, vegetation, and food for livestock and wildlife. It should be sensitive to (and differentiate itself from) off road use for livestock herding purposes. Lastly, the campaign will only prove successful if local authorities and governmental agencies from the soum are supportive and if it includes an enforceable component by local authorities.

Summary:

- OT is encouraged to consider initiating a public education program that informs employees and other drivers about roads, wildlife and livestock. The program should include economic benefits to healthy wildlife and benefits to the herding tradition in the region in order to engender a cultural respect for preserving wildlife. The program should promote the importance of wildlife, the importance of staying on the road ("off road is off limits") and the positive steps OT is taking to have a net positive impact on biodiversity. Specific components of the program could include:

1. An information kiosk at the airport.
2. A vehicle pullout with interpretive signing near the border with China on the OT-GS Road.
3. Warning signs and possibly highway striping at domestic livestock crossing areas.

5.4 Time of Day Restrictions on Vehicle Traffic

OT may consider limiting the times of day that traffic associated with the OT mine site is allowed to be on the road. Animals are more likely to approach and cross the roadway when there are very low traffic volumes (Gagnon et al. 2007). OT trucks could perhaps be scheduled to travel only during certain times of the day when human disturbance is relatively high already, and OT vehicles would not be allowed to travel the road when human disturbance, including travel by the public is low (e.g. a several hour long period late at night or early in the morning). If OT mine traffic is eliminated during certain hours, it would be advantageous to coordinate these times with other mining companies in the area (e.g. Energy Resources and the traffic between Tavan Tolgoi and the border) that may consider similar periods without mine traffic to reduce the barrier effect of the road to wildlife.

Khulan may be most active between 16:00 and 20:00 (Kaczensky referenced in ESIA 2013). However, if non-mine traffic is still relatively high during these hours, and if non-mine traffic cannot be controlled, it may not be very effective to restrict mine traffic between 16:00 and 20:00. It may be more effective to match a potential "curfew" for mine traffic with the lowest non-mine traffic volume.

The current and expected future levels of traffic flow on the OT-GS Road are in the range known to have an increasing impact on wildlife. The barrier effect and road avoidance behavior of wildlife is expected to increase. Even a modest reduction for a segment of time will likely reduce road avoidance by wildlife. Gavin and Komers (2006) found that there was an increase in the proportion of time pronghorn were vigilant when they were near roads with higher traffic (greater than 300 vehicles per day) compared to roads with lower traffic (less than 200 vehicles per day). As mentioned previously in the Road Avoidance Section, a road with 10,000 vehicles per day is known to be a near total barrier to pronghorn and there may be some barrier effect to khulan at 400 vehicles per day. The current traffic on the OT-GS Road is currently a few hundred vehicles per day and expected to grow by 2030 to 1600 vehicles per day (which includes 300 OT trucks). The road avoidance behavior in relation to traffic that Gavin and Komers found increased when a fawn was present in the herd. If OT mine traffic is only eliminated for these late night or early morning hours during certain seasons, then perhaps having no traffic associated with the mine during certain hours in the night is most beneficial during the calving period and right after calving, provided that there is no distinct seasonal movement pattern. Birth season for black-tailed gazelle is May and early June, while for khulan it is mid-June througg mid-July (Dorjdorem S., OT biodiversity supervisor, personal communication).

Summary:

- OT may consider scheduling low traffic volumes for a portion of each day. Initially, this should be between 16:00 and 20:00, but as non-mine traffic increases it may be most effective to base the time and length of such a “curfew” for low OT traffic volumes with periods of low non-mine traffic. This restriction could be implemented year-round or only for a few months (e.g. right after calving or during a distinct and predictable seasonal movement period if one is detected).

5.5 Wildlife Crossing Structure Types, Dimensions and Costs

Wildlife crossing structures as defined for this report are underpasses and overpasses specifically designed to allow wildlife to cross under or over the road. There are many different types and dimensions of wildlife crossing structures (Table 2; Figure 21 through Figure 27; Huijser et al. 2008, Clevenger & Huijser 2011). Different types and dimensions of crossing structures are more or less appropriate for specific wildlife species. An example of types and dimensions are most suitable for species in the northern Rockies in North America is shown in Table 3.

Table 2: Examples of commonly used wildlife crossing structure types, dimensions, materials and costs (Highway Service Centre, Parks Canada, Banff, Alberta, unpublished data, 2001). Costs were converted from 2001 Canadian dollars to 2001 US dollars by multiplying by 1.55 (2001 exchange rate). Cost indications for crossing structures relate to the structures only and do not include fencing and/or visual barriers.

Crossing structure type	Dimensions (width (road length) x height)	Materials	Cost/m US$	Unit cost US$	Comments
Structures					
Box culvert underpass	3.0 x 2.5 m	Concrete	40,000	115,000	Less cover required compared to metal culverts (= less cost)
Elliptical culvert underpass	7 m x 4 m	Corrugated steel	21,000-23,000	145-160,000	Greater time to install due to bolting together pieces
Open-span bridge underpass	~12 m x ~5 m	Concrete	38,000-55,000	450,000 to 650,000	Based on 12 m structure. Greater than 15 m width requires centre pier and expansion joints (>cost)
Overpass	52 m (w) x 70 m (l)	Concrete	31,000	1.6 million	Prefabricated concrete arches. 1-2 days to install arches. Ease of re-routing traffic.
Viaduct (underpass)	200 m section	Concrete spans	40,000	8 million	
Overpass tunnel (cut & cover)	200 m (w) x 27 m (l)		75,000	15 million	
Fencing					
Wood post - no apron	2.4 m high	Page wire	25		
Wood post - w/apron	2.4 m high	Page wire	32		
Steel post/ - w/apron	2.4 m high	Page wire	60		

Table 3: Suitability of different types of crossing structures for selected species in the Rocky Mountains, North America. (Clevenger & Huijser, 2011; Clevenger, unpublished data).

	Wildlife overpass	Open span bridge	Large mammal underpass	Medium mammal underpass	Small-medium mammal underpass	Animal detection system
Ungulates						
Deer spp.	●	●	●	⊗	⊗	●
Elk	●	●	○	⊗	⊗	●
Moose	●	●	○	⊗	⊗	●
Woodland caribou	?	?	?	⊗	⊗	●
Mountain goat	●	●	○	⊗	⊗	●
Bighorn sheep	●	●	○	⊗	⊗	●
Carnivores						
Fisher	●	●	○	⊗	⊗	⊗
Wolverine	●	?	?	?	⊗	⊗
Bobcat	●	●	●	●	●	⊗
Canada lynx	●	?	?	?	⊗	⊗
Cougar	●	●	●	⊗	⊗	⊗
Coyote	●	●	●	●	●	⊗
Wolf	●	●	○	⊗	⊗	⊗
Black bear	●	●	●	⊗	⊗	●
Grizzly bear	●	○	○	⊗	⊗	●

● Recommended/Optimum solution; ○ Possible if adapted to local conditions; ⊗ Not recommended; ? Unknown, more data required; — Not applicable

Figure 21: Landscape bridge Roertunnel, A73 motorway near Roermond is tunneled for 2.5 km under a small scale agricultural landscape and small river (Roer) and an urban area, near Roermond, The Netherlands (© Marcel Huijser).

Figure 22: Another view of the Landscape bridge Roertunnel, A73 motorway near Roermond, The Netherlands (© Marcel Huijser). This image is taken on top of the landscape bridge. The dark rectangle in the background is part of the tunnel structure.

Figure 23: Wildlife overpass designed for roe deer (*Capreolus capreolus*) and other species, Austria (© Marcel Huijser).

Figure 24: Elevated roadway, central Florida, USA (© Marcel Huijser).

Figure 25: Large overspan bridge, Tonto National Forest, Arizona, USA (© Marcel Huijser).

Figure 26: An underpass, likely several dozens of meters wide, designed for elk (*Cervus canadensis*) Tonto National Forest, Arizona, USA (© Marcel Huijser).

Figure 27: An underpass (14 m wide, 3 m high) designed for Florida Key deer (*Odocoileus virginianus clavium*) along US Hwy 1, Big Pine Key, Florida, USA (© Marcel Huijser).

The costs associated with wildlife crossing structures are almost always an important consideration in wildlife mitigation projects. However, there are not only costs associated with effective wildlife mitigation. There are also benefits as a result of reducing wildlife-vehicle collisions and associated monetary costs (property damage, human injuries, human fatalities, passive use costs etc.). From conservative analyses that were mostly based on vehicle repair costs and the costs associated with relatively rare human injuries and human fatalities, there are many road sections in North America where the costs associated with wildlife-vehicle collisions are higher than the costs associated with implementing mitigation measures, such as wildlife fencing, wildlife underpasses and wildlife overpasses (Huijser et al. 2009b). These cost-benefit analyses do not include passive use values such as the value of having viable wildlife populations and having preserved long distance migrations or nomadic movements characteristic for an ecosystem. If such values would be measured and included in similar cost-benefit analyses the economic thresholds for the implementation of mitigation measures would be lowered and more roads or road sections would qualify for mitigation based on an economic argument alone. The researchers stress that while the outcome of cost-benefit analyses can be important, the decision process should include other considerations as well.

The costs presented in Table 2 were obtained from engineering consultation by Banff National Park's Highway Service Centre (Parks Canada, unpublished data) in 2001, and they can be expected to have increased 5-10% since that time. Engineering costs, however, can be highly variable even in the same location, and are strongly influenced by the economic conditions at regional and national scales. During times of economic growth, construction costs can be up to 30% higher compared to times when there is a downturn in the economy, few construction projects, and a highly competitive environment for obtaining construction contracts.

Costs for construction of wildlife crossing mitigation in Mongolia are difficult to estimate for this report. While labor and materials may be relatively inexpensive, the remoteness of the area may increase costs.

Summary:

- There are numerous examples of different types and dimensions of wildlife crossing structures.
- The appropriate type and dimension of wildlife crossing structures is dependent on the target species.
- The benefits resulting from wildlife mitigation measures can outweigh the costs associated with the construction, operation and maintenance of the measures. The benefits can be based on a reduction in costs associated with collisions, potential consequent project delays owing to government or lender investigations, and/or passive use values, including preserving viable populations of threatened or endangered species and the ecological integrity of an ecosystem (e.g. characteristic long distance movements of selected wildlife species).

5.6 Visual Barriers and Fencing

Livestock fences are barriers

Fencing along the Trans-Mongolia railroad is known to be a barrier to Mongolian gazelles and khulan (Kaczensky et al. 2011, Olson 2012, Ito et al. 2013). The livestock fence is a relatively low fence mainly designed to keep livestock off the tracks (Figure 12). Substantial numbers of Mongolian gazelles get entangled in the fence when they try to cross the fenced railroad corridor and die (Ito et al. 2008, Olson 2012). Fences are also a substantial collision risk for birds such as Houbara Bustard, another of the other OT study area’s focal species. In other cases the Mongolian gazelles are killed directly by trains as they panic when a train approaches and they cannot quickly escape the fenced railroad corridor (Olson et al. 2012). While domestic sheep and goats may cause some design challenges, others have designed wildlife friendly livestock fences. Wildlife friendly livestock fences generally consist of smooth top and bottom wires (no barbs) to allow wildlife to jump over the fence or crawl under the fence without injuring themselves (Harrington & Conover 2006, Montana Fish, Wildlife & Parks 2012). The bottom wire may also be higher off the ground (minimum 41-46 cm) to allow young to crawl under the fence (Montana Fish, Wildlife & Parks 2012). Note that livestock fences (or other measures that increase the barrier effect or roads and railroads), should, as a general rule, not be implemented without also providing for effective safe crossing opportunities for wildlife. If livestock fences are implemented along roads or railroads, then the design of the fences should be modified so that they pose less of a hazard to wildlife. The optimal design is a livestock fence that creates a barrier for livestock (sheep, goats, cattle, horses, camels), is not a collision risk for birds and can be crossed relatively easily by Mongolian gazelle and black-tailed gazelle, and potentially also by argali sheep. In addition, the fences should not be a substantial risk to low flying birds such as houbara bustard (*Chlamydotis undulate*). Based their unwillingness or inability to cross the livestock fences along the Trans-Mongolian railroad, Khulan are less likely to be able to cross any type of livestock fencing and they will likely completely depend on well positioned and designed crossing structures.

Wildlife fencing

Wildlife fencing is usually an integral component of a highway mitigation project that includes underpasses and overpasses for wildlife. Wildlife fencing fulfills two major functions:

1. Keep wildlife from accessing the road corridor and thus reduce wildlife-vehicle collisions.
2. Guide wildlife to safe crossing opportunities; e.g. wildlife underpasses or wildlife overpasses. Wildlife use of crossing structures and overall road crossing frequency can increase as a result of continuous fencing in between safe crossing opportunities (Gagnon et al. 2007).

Continuous wildlife fencing is not likely to be implemented along the project roads though for the following reasons:

1. Livestock herders are likely opposed to continuous wildlife fencing as they may want to have their livestock cross the road anywhere rather than only at selected livestock crossings or wildlife crossing structures.
2. The Gobi, as well as most of Mongolia, is a very open landscape and wildlife fences are likely to negatively affect landscape aesthetics.
3. Unless effective wildlife crossing structures are implemented at short intervals along the entire road length (e.g. up to several kilometers apart), continuous fencing may also do harm by blocking potential at grade wildlife crossings without providing for nearby safe crossing opportunities.
4. Mongolia is known as “the land without fences”; fences affect what makes Mongolia unique.
5. Fencing is a significant collision risk for low flying birds such as the houbara bustard (*Chlamydotis undulate*) (IUCN 2013).

It is considered good practice to not increase the barrier effect of roads and traffic without also providing for safe and effective crossing opportunities for wildlife. Conversely, it is considered bad practice to increase the barrier effect of infrastructure, e.g. through wildlife fences, without also providing for safe and effective crossing opportunities for wildlife. As an example, livestock fencing along the Trans-Mongolia railroad is known to be a barrier to Mongolian gazelles and khulan (Ito et al. 2008, Kaczensky et al. 2011, Ito et al. 2013). This, despite the fact that the fence is a relatively low fence, mainly designed to keep livestock off the tracks, and that there are culverts and bridges to allow for water flow and livestock movements. Some of the culverts are behind the livestock fence resulting in reduced access for wildlife while others have the livestock fence tied in to the sidewalls of the structure or have the fence continue above the structure (see Figure 8 and Figure 9). Regardless, the structures and configurations present along the Trans-Mongolian railroad do not allow for sufficient wildlife movement; the railroad corridor with livestock fencing and culverts and bridges for water flow and livestock movements are a very substantial barrier to large ungulates. In addition, substantial numbers of Mongolian gazelles get entangled in the fence when they try to cross the fenced railroad corridor and die or are hit by trains directly in the fenced railroad corridor (Ito et al. 2008, Olson 2012).

Since continuous wildlife fencing is unlikely to be implemented along the project roads, other measures that may guide wildlife to safe crossing opportunities should be considered. The researchers distinguished between two approaches:

5.6.1 Approach 1: Minimizing Visual Disturbance from the Road in the Vicinity of Safe Crossing Opportunities for Wildlife.

As a result of legal and illegal hunting, the ungulate species are likely to keep their distance from roads, especially if traffic is present. Therefore, the ungulate use of the structures may depend on how well traffic and other human disturbance along the road corridor is hidden from sight. Since a landscape bridge hides the road from sight over a long distance by definition (e.g. 1000 m buried road length, excluding approaches), a landscape bridge is likely to minimize visual and other disturbance from the road corridor to wildlife by its own design. Overpasses as defined for this report (50-70 m wide) cover much shorter road length and may require visual barriers (screens) for at least several hundreds of meters alongside the road adjacent to the crossing opportunity (see earlier). Note that both landscape bridges and overpasses also require fencing on top of the structures to keep wildlife from jumping down onto the road. Such wildlife fences are typically integrated into a visual barrier that may also reduce noise disturbance, at least to a certain extent (e.g. berms, wooden fences or screens) (Figure 10, Figure 11, Figure 28, Figure 29).

Figure 28: Wildlife fence and visual barrier integrated into one structure on top of wildlife overpass, The Netherlands (© Marcel Huijser).

Figure 29: Wildlife fence (physical barrier) on the right and earthen berm with shrubs (visual and sound barrier) on the left on top of wildlife overpass, Austria (© Marcel Huijser).

It is recommended that at least several hundreds of meters of visual screens be combined with wildlife fencing on both sides of a crossing structure (see Section 4.4). The visual screens and wildlife fence should be a barrier to large ungulates such as khulan, black-tailed gazelle, Mongolian gazelle, argali, and livestock. The visual barrier and wildlife fence can also keep vehicles and people from leaving the road in the vicinity from the crossing structures and all should preferably be integrated into one design. The wildlife fence should be a near impermeable barrier to wild ungulates and livestock. Care must be taken that animals do not get entangled in the wildlife fence; the fence should have a different design than the livestock fence present along the Trans-Mongolian railroad (Ito et al. 2008, Olson 2012). This may be achieved through smaller meshes of the fence and taller fences (e.g. about 2.4 m high) (Figure 30). The visual screens may need to be higher as the objective is to obstruct the view of traffic, including large heavy trucks. The exact height of the visual barrier depends on the height of the trucks expected to drive on the road and the position of the base of the fence compared to the roadbed and the surrounding landscape. If the road is lowered when approaching a landscape bridge or wildlife overpass, the visual screen can be reduced in height, though the wildlife fence that may be an integral part of the structure should remain at about 2.4 m high at a minimum. On the other hand, consider a wildlife fence as serving both as a visual barrier as well as reducing the risk of collisions for low flying birds. Strong wind may cause challenges with high visual barriers and care should be taken that the construction can withstand the Gobi environment. Note: A visual screen and wildlife fence is not to be confused with a wildlife friendly livestock fence. A wildlife friendly livestock fence is designed to be a barrier for livestock but not a substantial barrier and not a substantial hazard to wildlife.

Figure 30: A 2.4 m high wildlife fence, designed to be a barrier to ungulates such as deer (*Odocoileus* spp.) and pronghorn (*Antilocapra americana*), Hwy 2, near Havre, Montana, USA (© Marcel Huijser).

5.6.2 Approach 2: Use Cairns, or a Combination of Ditches and Berms to Guide Wildlife Towards Safe Crossing Opportunities of the Road.

In open landscapes across the northern hemisphere, humans have used cairns or berms and ditches to funnel ungulates to areas where they could be trapped or killed directly. These cairns or berms and ditches were used a very long time ago, perhaps several thousand or many thousands of years ago, but they may also have a modern application in open landscapes. They could encourage ungulates to approach roads where safe crossing opportunities have been provided. Cairns or berms and ditches could perhaps have a similar function as wildlife fencing. The difference is that while wildlife fencing is typically placed alongside the road and serves as a physical barrier, the cairns and berms and ditches would radiate out into the surrounding landscape at an angle and direct wildlife towards the safe crossing opportunities. The cairns or berms and ditches are not necessarily a substantial physical barrier to the ungulates. They may primarily serve as a behavioral barrier as ungulates tend to follow the cairns or berms and ditches rather than cross them.

Examples of cairns or berms and ditches:

- On the Tibetan plateau there are “long irregular lines of stone mounds, many no more than a foot high, along hillsides and low passes where chiru migrate... … two stone lines, some 500 feet long and wide apart at the mouth, are built to converge and create a funnel…. at the end of the funnel are anywhere from three to twenty or more traditional foot traps” (Schaller 2012). Note: Chiru are Tibetan antelope. Fox and Dorji (2009) also report on these structures on the Tibetan Plateau. The lines are many hundreds of meters long, up to several kilometers, and some are over 5 km in length. The lines or cairns are relatively low: 10-20 cm high piles of rocks or a single large rock, or sometimes the piles consist of dirt or sand with rocks placed upright on top of the piles.
- Somewhat different structures are arrowhead-shaped walls (“arrans”) on the Ustyurt Plateau, Uzbekistan, and in the Sam desert and south-east of the Tasai well in Kazakhstan (Bull & Esipov 2013). Arrans are basically berms and ditches in the shape of an arrowhead. The sides of the arrow are about 700 m long. The base of the arrowhead acts like the funnel and the arrowhead itself acts like a corral. These structures were likely used to concentrate or trap and then kill onager (*Equus hemionus*), saiga (*Saiga tatarica*), black-tailed gazelle, and Ustyurt sheep (*Ovis vignei*) (Bull & Esipov 2013).
- “Desert kites” are triangular-shaped stone structures designed to trap and kill wild ungulates (Bar-Oz et al. 2011a). They have two long converging low stone walls (about 40-60 cm high) with a circular enclosure at the tip of the triangle where the two walls meet. The walls may also connect to a cliff rather than a circular enclosure (Bar-Oz et al. 2011a). The stone walls may be several hundreds of meters or sometimes several kilometers long (Bar-Oz et al. 2011a). They are found from Arabia to southeastern Turkey along what is thought to be an historic migration route for black-tailed gazelle. *(*Bar-Oz et al. 2011b). Other species that may have been killed using these structures are

onager, Dorcas gazelle (*Gazella dorcas),* hartebeest (*Alcelaphus buselaphus*), arabian oryx (*Oryx leucoryx*), and ostrich (*Struthio camelus*) (Bar-Oz et al., 2011a; b).

- On the plains and Great Basin in North America, cairns (piles of earth, buffalo chips, brush, or stones) or fences composed of stones, snow, brush, logs, and/or living trees were used as drive lines (Lubinski 1999; Barsh & Marlor 2003). People situated at regular intervals may have also been used as a drive line. These drive lanes were used to hunt pronghorn and bison (*Bison bison*) (Lubinski 1999; Barsh & Marlor 2003). The drive lanes may have been about 500 m long (for pronghorn) up to about 5 km for bison (Reeves 1978, Sundstrom 2000). Cairns were about 90 cm high at one site (Reeves 1978).
- Game-drive systems in alpine or tundra ecosystems of North America consist of low rock walls or lines of cairns used as drift fences or combined into U-shaped or funnel-shaped configurations (Benedict 2005). Drive walls can be up to 1 km long and about 1 m high (Benedict 2005). Sticks standing upright in the walls or cairns may have been used to scare the animals and keep them moving further into the funnel. Structures that have cairns may have them placed about 2-4 m apart (Benedict 2005). Blinds allowed the hunters to kill animals as they walked or ran by at close range. In the Rocky Mountains the species that were hunted using these structures were likely mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*) and bighorn sheep. In the arctic the focal species were likely caribou (*Rangifer tarandus*) and muskoxen (*Ovibos moschatus*).
- In Norway, “drift fences made of long rows of human-like, closely spaced stone cairns or wooden sticks or poles creating funnel-shaped systems” were used to drive wild reindeer (*Rangifer tarandus*) into a lake where they would be killed by people from boats (Indrelid & Hufthammer 2011).

Note that the authors of this report are not always certain if the cairns and berms and ditches worked with or without humans hiding behind them or people chasing the animals from behind, further and further into the funnels. It seems that at least some of the structures, e.g. those for the Tibetan antelope, did not require people driving the animals into the funnel or people hiding along the sides of the funnel to scare the animals back into the funnel if they were about to breach the drive lines. The researchers suggest experimenting with cairns and berms and ditches to see if they could help funnel khulan, black-tailed gazelle, Mongolian gazelle, and potentially also argali towards safe crossing opportunities (Figure 31).

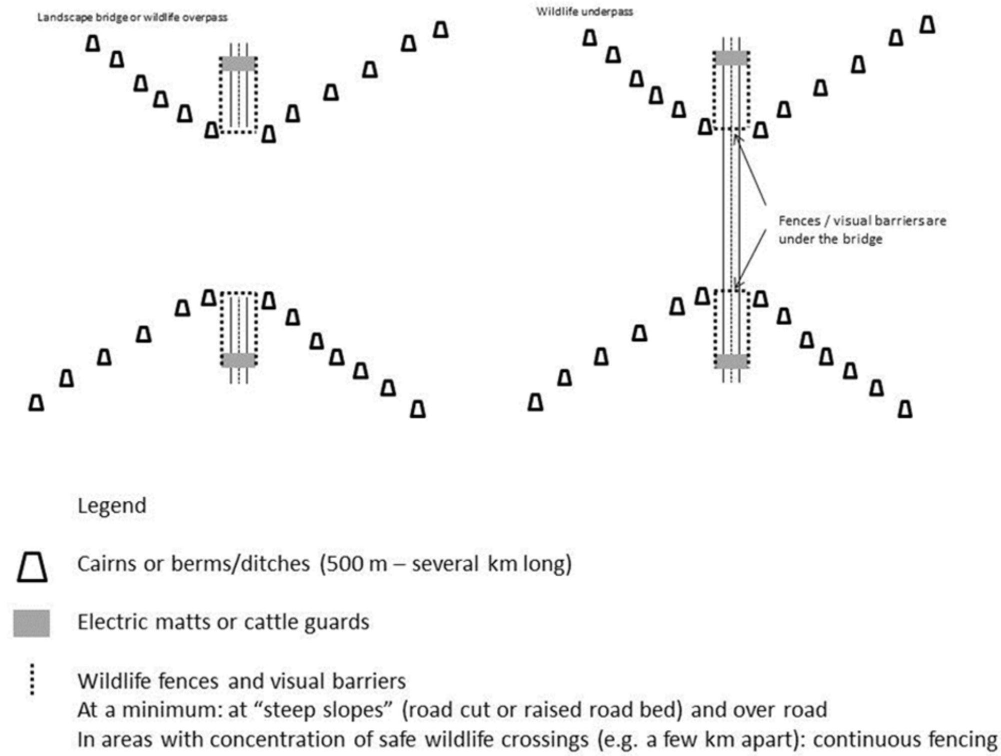

Figure 31: Schematic configuration of wildlife fences and visual barriers and cairns or berms and ditches in association with landscape bridges, overpasses, overspan bridges or wildlife underpasses. One could consider adding additional lines (cairns or berms and ditches), essentially creating multiple funnels that lead to a safe crossing opportunity.

Summary:

- Livestock fencing, similar to that used on the Trans-Mongolian railroad, should not be used.
- If used, livestock fencing should have a modified design to pose less of a hazard to wildlife and include safe crossing opportunities for wildlife.
- Use of wildlife fencing and visual barriers near wildlife crossing structures is crucial to the successful use of the structure.
- Preferably, wildlife fencing should also serve as a visual barrier to reduce the potential risk for bird strikes.
- Cairns, ditches and berms should be considered near structures to guide wildlife to the structures.

5.7 Carcass Removal

When OT staff encounter road killed wildlife, the environmental team is notified and the carcass is removed. In addition to OT staff opportunistically monitoring the road while conducting other activities, a dedicated monitoring and inventory run is made every month. WTI recommends that these practices continue. The prompt removal will minimize potential secondary road kills (e.g. scavengers). Currently mortality due to vehicle strikes is minimal.

Summary:

- OT should continue formal record keeping of wildlife kills along the OT-GS Road.

5.8 Physical Barriers to Prevent Poachers from Opportunistically Leaving Road

Barriers (boulders, berm and ditches, or other obstacles) alongside the project roads have been suggested already (TBC and FFI, 2012). The purpose of these barriers would be to prevent poachers from opportunistically leaving the road and chasing after wildlife. This would also minimize damage to plants (food for livestock and wild ungulates) grasslands and soil. These barriers should not be a barrier to wildlife, but should prevent vehicles from leaving the roadway. There are several methods that could be used. Several are discussed below with recommendations at the end of this section.

Bollards are often used to prevent vehicles from entering shared use pathways (i.e., bike pathways) or paid parking lots. Figure 32 shows an example in Grand Teton National Park, USA.

Figure 32: Example of bollard and sign post to prevent auto use of bike path (Source: Pat McGowen).

There are numerous sizes and shapes of bollards, as well as materials used to construct them. Similar to the wooden posts shown in Figure 33, guardrail posts could also be used. Wood material can be more aesthetically pleasing, but may be vulnerable to being removed for fuel or construction material. Another common design is a metal post about 15 cm in diameter filled with concrete. A lower cost installation could be possible by using galvanized metal posts used in chain-link fencing shown in Figure 33. Although less expensive (around $10 each), these may not withstand the force of a determined driver running them over.

Figure 33: Aluminum fence posts (Source: Ed Cox).

Large boulders were suggested in previous OT Project biodiversity documents. The general consensus seems to be that the number and size (large enough so as not to be easily moved) would be cost prohibitive. An alternative is to use gabion baskets with smaller sized rock fill (Figure 34). These can be filled with gravel or sand, but require a geo-fabric. These are typically used in building low cost retaining walls but have been used as a vehicle barrier for security reasons. Material cost for a three foot (0.91m) basket is around $40 each. Adding geo-fabric to allow filling with gravel and sandy material would increase the cost by around $5 (Kimmes, K. personal communication). This cost could be reduced significantly by eliminating the top cover and negotiating a bulk purchase. The cost does not include the rock fill or installation. Avoid rock that could result in acid mine drainage.

Figure 34: Gabion basket (Source: www.gabionbaskets.net)

Ditches and berms could be used parallel to the entire length of the roadway. The ditch should probably be at least 1m deep with the excavated material building a berm directly next to the ditch. This could be the most cost effective as there are no material costs, but would likely require more maintenance as wind and water erosion might soften the slopes making them passable by a vehicle. Another downside to this method is that it might create a barrier to wildlife and livestock.

Fencing and visual barriers were discussed earlier as a tool to funnel wildlife to crossing structures and minimize the visual and auditory impact of vehicles near crossing structures. Fencing and visual barriers can serve multiple purposes, including keeping vehicles from leaving the roadway, at least in the immediate vicinity of wildlife crossing structures.

5.8.1 Physical Barrier Recommendation

For all of these physical barriers, the construction cost is significant considering the lengths of roadway (about 100 km for the OT-GS Road alone). In addition, physical barriers would require at least some type of maintenance which could also be a significant cost. Apart from concerns about the scale over which the barriers may be implemented, there is a direct conflict with how people in Mongolia currently drive; they drive almost anywhere, regardless of whether there is a road. This means that people may go to great lengths removing or breaching the barriers, at least at selected locations, thereby vastly reducing the effectiveness of the barriers. The negative impact to reducing the free movement of local road users could result in significant negative public perception for OT. Furthermore, people are accustomed to moving their livestock anywhere, and they would likely expect to be able to cross the road indiscriminately. Boulders are unlikely to be an obstacle for livestock, but berms and ditches may be a problem, particularly for domesticated Bactrian camels that are said to not be able to lift their feet very high. Again, this conflict suggests that the potential barriers will likely be compromised at a large scale. Finally, lines of boulders or berms and ditches over long distances may increase the barrier effect of the road for wild ungulates (based on behavior, not a physical barrier, such as fencing), and such continuous barriers may only be acceptable in road sections that have a concentration of safe wildlife crossing opportunities or domestic livestock crossings.

We suggest not implementing barriers for vehicles along the entire road length. It is recommended to implement barriers in the immediate vicinity of wildlife crossing structures to minimize both people leaving the road and human related disturbance close to the wildlife crossings. In road sections that have a concentration of wildlife crossings (e.g. up to 2 km interval between structures), barriers for vehicles may be continuous in between the crossings. It is advisable to integrate a barrier for vehicles into the wildlife fence and visual screens that are also suggested at and near the wildlife crossing structures (see Section 5.6).

If barriers are used, spacing between obstructions should be, at a maximum, 2 meters. This is based on a typical passenger car (sedan) being approximately 2.1 m in width (AASHTO 2011). However, the US Forest Service Equestrian Design Guide recommends three to four feet (0.9-1.2 m) spacing to prevent ATV use.

Any element used should be placed at least 10 m from the edge of the travelled lane in order to allow vehicles that accidentally depart from the road to come to a complete stop before colliding with these objects.

The magnitude of poaching with vehicles is not well known for the area. To mitigate the poaching problem, it is recommended that regulation and enforcement of both poaching and off road departures in conjunction with a public awareness campaign will be a better use of resources than a roadside barrier along the entire length of the OT roads.

Summary:

- Poaching and vehicle road departures should be mitigated primarily through education and enforcement.
- Barriers that discourage vehicles from leaving or accessing the road are not recommended for the entire length of the roads. They are only suggested in the (1) immediate vicinity of safe wildlife crossing opportunities, and (2) in areas that have a concentration of safe crossing opportunities (e.g. less than 2 km apart).
- Barriers for vehicles should be integrated with wildlife fences and visual barriers that are installed at and near safe wildlife crossing opportunities so that multiple purposes can be served: funneling animals to the structure, reducing visual disturbance, and keeping vehicles from driving off-road.

6 WILDLIFE CROSSING MITIGATION

6.1 Existing Recommendations for Wildlife Crossing Mitigation

The current proposal for mitigating fragmentation effects of the OT-GS Road upgrade includes a minimum of 16 wildlife underpasses spaced at roughly 6 km intervals (TBC & FFI 2012a). The spacing interval of the underpasses was based on the linear measure of home range area (Bissonette & Adair 2008) and correlated to the average distances walked by animals in one day. This distance is roughly 12 km for khulan and 3 km for gazelles (Kaczensky et al. 2006, Olson et al. 2010, Mueller et al. 2011). There were no recommendations for fencing associated with the proposed 16 wildlife underpasses (TBC & FFI 2012).

Each underpass was designed to have an open span measuring at a minimum of 12 m (road length) and 4.5 m high. Underpasses were chosen as the preferred crossing structure type based on preliminary data that suggested that open plains dwelling ungulates were unwilling to use overpasses, primarily because the slope associated with overpasses would not allow khulan to see the other side of the road. Further, khulan and other nomadic and migratory plains ungulates have been largely recorded using underpasses (TBC & FFI 2011). However, recent monitoring of another open habitat species, pronghorn (*Antilocapra americana*), suggests that overpasses are much more suitable for this species than underpasses (H. Sawyer, personal communication).

The proposed wildlife underpass does not include any guiding elements, such as fencing, that will lead animals to the crossing structure. The proposed mitigation design, without fencing, is lacking some form of visual barrier other than right on top of the underpass, and the relatively small minimum dimensions would likely not be suitable for the focal species in the project area; we think that these structures would not allow for sufficient road crossings by the focal species to substantially mitigate the fragmentation effects of the upgraded OT-GS Road. We provide recommendations for mitigating the OT-GS Road that may be more effective for the target species and that also allow for an adaptive management strategy for the type and dimensions of structures.

6.2 Number and Spacing of Wildlife Crossing Structures

Regarding the 6 km spacing interval proposed for wildlife crossing structures, we agree that this is a useful guideline in the sense that it is based on an ecological parameter: the daily movement distances for the target species. Basing the spacing, type and dimensions on population viability modeling or wildlife movement data would be better, though many parameters would have to be estimated or guessed. Further complications are:

- Unlike resident individuals or migratory species with predictable movement patterns, the study area's focal species are more nomadic and their movements in the Gobi are largely unpredictable in time and space. Their nomadic movements are heavily influenced by spatial and temporal distribution of rainfall events. Thus, where and when these ungulates will need to cross the OT-GS Road may be approach a random distribution.

- Unlike resident individuals or individuals that migrate seasonally, the focal species and individuals do not necessarily have the opportunity to learn about the location of the wildlife crossing structures and that it is safe to use them. This suggests that the number, type, and dimensions of crossing structures should be more abundant and more inviting than for individuals that have substantial exposure to the structures and that have an opportunity to learn about their location and that it is safe to use them.

As the authors of this report currently do not have the resources to conduct a more sophisticated analysis with regard to appropriate spacing of crossing structures based on population viability modeling or wildlife movement data (e.g. through GPS radio collar data), the number of crossing structures and their spacing is largely left uncontested. However, rather than a strict 6 km spacing between crossing structures the researchers suggest:

- Implementing structures in different habitats (e.g. both the granitic rocky outcrops and the central valley) rather than only in one ecozone. This makes it more likely that the crossing structures will serve the species that are present in the different habitat types alongside the road.
- Basing the location of the crossing structures on regular live sightings of the focal species on or near the road. This should minimize the risk that wildlife crossing structures are constructed where the target species do not come close to the road or do not cross the road.
- Not constructing wildlife crossing structures where other unmitigated roads run parallel to the OT-GS Road (e.g. at a few hundred meters distance) and where wildlife may be unable to cross the larger transportation corridor.

As more research and information is obtained on the distribution and movements of the focal species in the study area, and their response to initial mitigation (i.e. if a phased approach is adopted to the construction of crossing structures), the spacing requirement may be revised.

It is more common for road sections that have a concentration of wildlife crossing structures for large mammals to typically have the crossing structures spaced closer together than 6 km. For example the average spacing for large mammal crossing structures in Montana (US Hwy 93 North and South), I-75 in Florida, SR 260 in Arizona, Banff National Park in Canada, and ongoing reconstruction on I-90 in Washington State is 1.9 km (the range for the average spacing of structures in these individual areas is 0.8-2.9 km). Thus the current recommended spacing for crossing structures along the OT-GS Road is about 3 times greater than along roads with a concentration of crossing structures in North America. However, the 1.9 km spacing is simply what people have done elsewhere. It is not necessarily based on what may be needed ecologically for the OT-GS Road, since the requirements for the focal species in the Gobi are different from the large mammal species in North America.

If evidence becomes available based on wildlife observations or wildlife movement data (actual data or modeling)) that the focal species along the OT-GS Road are concentrated in certain areas, then it is preferable for the wildlife crossing structures to be concentrated in these areas as well.

It is suggested to place wildlife crossing structures along road sections where existing data suggest the focal species regularly cross the road. It is not recommend a consistent 6 km spacing between the wildlife crossing structures without supporting empirical data. However, it is recognized that near term wildlife data (1-2 years) may be from a very limited time period and that the recorded wildlife use may be the result of random precipitation. Therefore, it is also suggested to have multiple crossing structures in each of the three different ecozones (see Section 6.3.1) along the OT-GS Road.

6.3 **Our Approach**

6.3.1 A Sectional Approach

The 106.8 km road OT-GS Road upgrade traverses important habitat of nomadic or migratory ungulate species in the southeastern Gobi. Along this road corridor, three broad land classification zones can be described from north to south: 1) granitic outcrops around the OT mine site, 2) central valley, and 3) Small Gobi B strictly protected area (Figure 36).

The granitic outcrop zone extends about 25 km from the OT mine site south to about the proposed location of mitigation site #6 (Figure 36). This area is characterized by hilly terrain with rock outcroppings and most suitable habitat for argali, although black-tailed gazelle and occasional khulan also move through this area (Figure 36). Potential mitigation in the granitic outcrop zone should primarily target argali, and to a lesser extent black-tailed gazelle and khulan.

The central valley is the most extensive zone (about 40 km) occupied by the road upgrade from the proposed mitigation site #6 location (Figure 36) to Tsagaan khad (White Rock). This area has little or no topographic relief and is likely prime habitat for khulan and also important habitat for black-tailed gazelle (Figure 36). Potential mitigation in the central valley should primarily target black-tailed gazelle and khulan.

The last and southernmost zone (about 15 km) is situated within the Small Gobi B strictly protected area (Small Gobi B SPA). This area has high ecological values and consists of a mix of rolling hills and open plans dominated by saxaul plant communities. Khulan are most common of the four focal ungulates in this area and would benefit by increased permeability of the OT-GS Road. Potential mitigation in the Small Gobi B SPA should primarily target khulan. However, this area is also heavily impacted by the Tavan Tolgoi coal road, which intersects the OT-GS Road at Tsagaan khad. The high volume of constant truck traffic through this area is likely a complete barrier to ungulate movement (Figure 37). The researchers currently do not recommend wildlife mitigation measures for this road section for the following reasons:

- Currently there are multiple roads that parallel each other adjacent to or through the Small Gobi B SPA. Mitigating only the road associated with Oyu Tolgoi is unlikely to benefit wildlife unless the other roads are mitigated at the same time. Of course it would be much preferred if all roads through the Small Gobi B SPA were located outside the strictly protected area (“avoidance”) or if they would be combined into one road, which not only reduces the footprint of the transportation corridor but also enables more effective mitigation at a lower cost.

- Even if the other roads through the Small Gobi B SPA would also be mitigated, the researchers still have concerns about the very high traffic volume of large trucks and the road dust and coal dust associated with these roads (Figure 36). The high traffic volume, noise and dust may keep animals away from potential future crossing structures unless the road surfaces are improved (i.e. only paved roads) and substantial noise and visual barriers are installed.
- The researchers recommend building the first wildlife crossing structures where khulan and black-tailed gazelle are most abundant and where they are most likely to approach and cross the road. This is essential as data on the potential use of wildlife crossing structures by these species needs to be available as soon as possible to help guide decisions on potential additional mitigation measures in later phases. Structures in the Small Gobi B SPA are unlikely to generate such data though, primarily because of the other roads that parallel the road associated with the Oyu Tolgoi mine site.

Wildlife crossing structures should only be implemented in the small Gobi B SPA if a comprehensive wildlife mitigation plan is developed and implemented for the area that includes all transportation facilities in this area. We recommend that the wildlife mitigation plan be given a high priority.

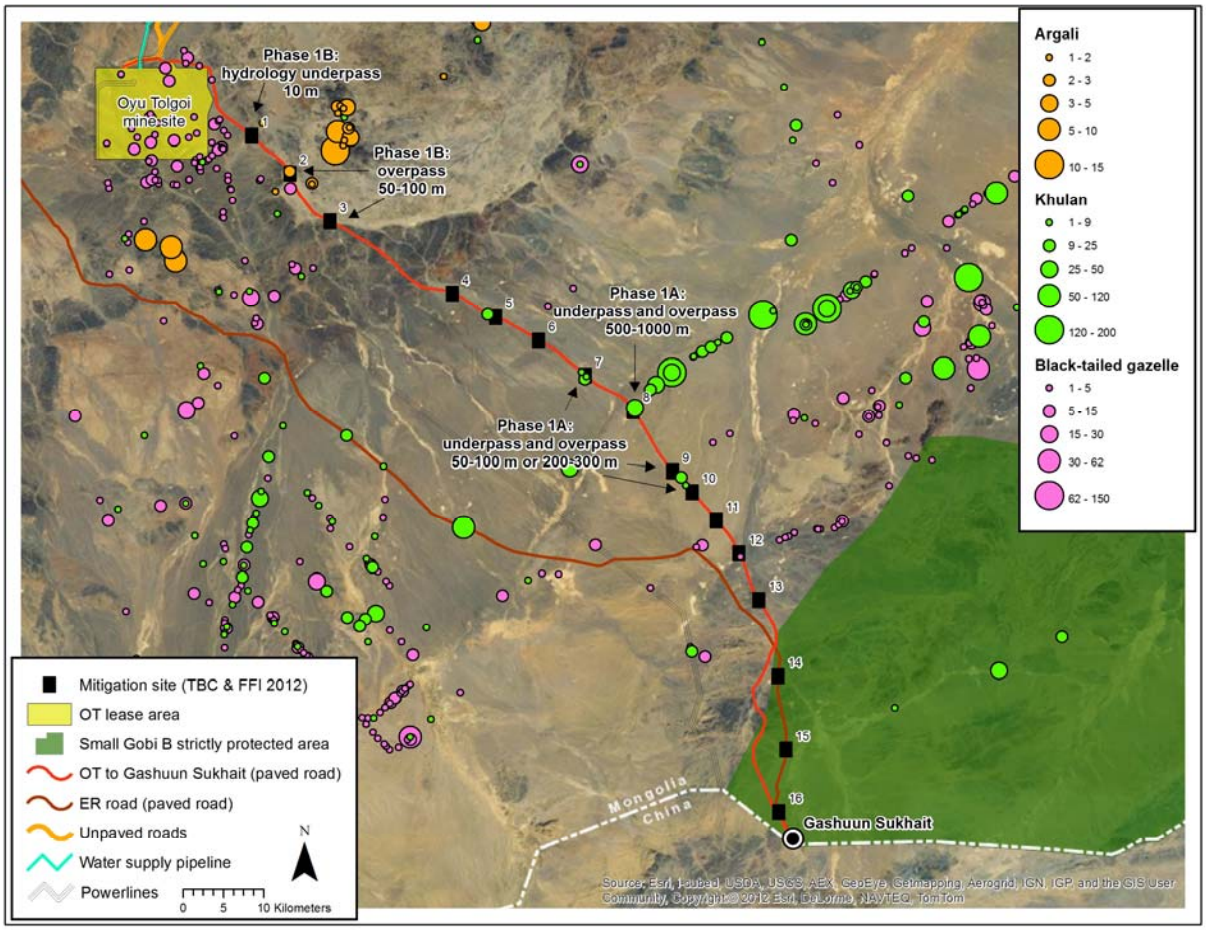

Figure 35: "Proposed" underpass locations, based on OT data, and survey data (search effort not consistent across study area) on relative abundance of argali, khulan and black-tailed gazelle. Note that the current document contains different recommendations (see later in Chapter 6 and 7).

Figure 36: The unpaved coal haul road associated with the Tavan Tolgoi coal mine with coal trucks in Small Gobi B SPA just north of Gashuun Sukhait (border Mongolia/China), Gobi, Ömnögovi, Mongolia (© Marcel Huijser). In the foreground (lower left corner) is the currently unpaved road from Oyu Tolgoi (mine site) to Gashuun Sukhait (border Mongolia/China). Behind the dust from the trucks is a paved toll road for the coal trucks that seems to receive much less use than the gravel road that does not require a toll and that does not have an enforced weight limit for the coal trucks.

6.3.2 Crossing Structure Types and Dimensions Considered

Based on the sectional approach we advise different crossing structure dimensions for each section:

1. Crossing structure dimensions that are primarily intended to pass argali, perhaps also suitable for black-tailed gazelle and khulan. These structures are recommended for the granitic outcrop zone extending south of the OT mine site.
2. Crossing structure dimensions that are primarily intended to pass black-tailed gazelle and khulan. These structures are recommended for the central valley.

Rather than recommending only one or a few crossing structure types and dimensions, Section 6 explores multiple types and dimensions. The suitability classification for the crossing structure types and dimensions discussed ranges from “not-recommended” to “optimal” for different attributes and their overall suitability for the different focal species (Table 4).

The smallest width (road length) of the structures is 12 m. This is consistent with the dimensions of the underpasses that were originally proposed (TBC & FFI 2011). However, the researchers consider this type and dimension of wildlife crossing structure outside of the range that is potentially suitable for argali, khulan and gazelles (Table 4).

The next smallest width (road length) of the structures is 50-100 m. Although availability of materials and construction practices in Mongolia may differ, there are several examples in this report of structures 50 m or wider that are less than the US$5 million estimated construction costs of the currently proposed 12 m structures. A more detailed engineering estimate should be completed, but we suspect that the cost for a 50-100 m wide structure may not be excessively greater than the currently planned amount. We estimate that a 50-100 m width could potentially be very good for argali, good for gazelles, and suboptimal khulan, but 50-100 m wide structures are likely not optimal. We consider structures of 500-1000 m width (road length) potentially optimal for both species, though it may be at the lower end of what could be considered optimal, especially for khulan. Structures that are 200-300 m wide (road-length) are an intermediate option that may well be optimal for black-tailed gazelle, but not for khulan. More specific justification for the types and dimensions suggested for consideration are described below and are summarized in Table 4.

Table 4: Structural attributes of crossing structure types for the OT-GS Road and their estimated suitability based on focal species' ecological and behavioral needs.

	Overpass 500-1000 m	**Overpass 200-300 m**	**Overpass 50-70 m**	**Underpass 500-1000 m**	**Underpass 200-300 m**	**Underpass 50-70 m**	**Underpass 12 m**
Visibility through or across structure	+++	++	+	++	+	-	- -
Lack of disturbance: visual presence road	+++	++	+	-	-	- -	- -
Lack of disturbance: traffic visibility and noise	+++	++	+	-	-	- -	- -
Lack of disturbance: livestock loitering (physical obstruction to wildlife and smell (urine feces))	+++	+++	++	-	- -	- -	- -
Estimated suitability for khulan	+++	++	-	+	+	- -	- -
Estimated suitability for black-tailed gazelle	+++	+++	+	++	++	- -	- -
Estimated suitability for Mongolian gazelle	+++	+++	+	++	++	- -	- -
Estimated suitability for argali	+++	+++	++	-	-	- -	- -

+++ Optimal, ++ Very good, + Good, - Suboptimal, - - Not recommended

Below is a justification for the structures that we recommend and their potential suitability for mitigating the fragmentation of the OT-GS Road.

1. Overpass 500-1000 m wide

This is the largest structure recommended for consideration for mitigating fragmentation effects of the OT-GS Road. The width of the structure is largely based on known road avoidance distances (ca. 500 m) of khulan, likely the most sensitive of the focal species (Kaczensky et al. 2006, Ito et al. 2013, Lian et al. 2012). The overpass is essentially a tunnel, “cut and cover”, with wildlife passing above traffic that is well below grade. From the perspective of wildlife, there are no earthen ramps or slopes when approaching the overpass and the view distance across the overpass is similar to the areas away from the road (i.e. practically unhindered since the terrain in the central valley is extremely flat). There are no or few minor modifications to the terrain and vegetation at or adjacent to the site. After construction, topsoil and vegetation on top of the overpass should be similar to the surroundings away from the road. Due to their large size they are likely to be used by all or almost all wildlife species present in the ecosystem. We expect that this type of structure will fully mitigate the barrier effect for nearly all species, at least for the road length over which it is implemented. In addition, long sections of buried road also result in no road departures by vehicles chasing and potentially poaching wildlife. The road length over which this applies is not only the width of the structures (road length), but also the associated barriers for vehicles/wildlife fencing/visual barriers that may extent for another 500 m or longer from each structure.

2. Overpass 200-300 m wide

This intermediate sized overpass is estimated to be likely suitable for black-tailed gazelle and Mongolian gazelle, based on Tibetan gazelle using a similarly wide underpass and several individual gazelles in Israel using a 150 m wide overpass (see earlier). Khulan may or may not use this structure in acceptable numbers. This structure is expected to be optimal for argali if constructed at the correct location.

3. Overpass 50-100 m wide

This is the narrowest overpass. It is likely to be used by black-tailed gazelle, but perhaps not in acceptable numbers. This is based on pronghorn using a 46 m wide overpass in substantial numbers in Wyoming (USA). In addition, and perhaps more comparable because of their fear of humans and human made structures and vehicles, individual gazelles have used a 50 m wide overpass in Israel (see earlier). Khulan is not expected to use this structure or only in very low numbers. A 50-100 m wide overpass is expected however to allow for substantial use by argali, based on their similarity to desert bighorn sheep in Arizona (USA). The width of the structure was adjusted for the body size (weight) of argali compared to that for desert bighorn sheep.

4. Underpass 500-1000 m wide, 5-7 m high

These are the largest underpass structures for wildlife use. The large span and vertical clearance of viaducts generally allow for use by a wide range of wildlife. Long viaducts have been used to pass Tibetan antelope under the Qinghai–Tibet railway. Along that railway there are more than 100 underpasses greater than 100 m wide, but there is only one structure through which the vast majority (90-98%) of Tibetan antelope pass. This is a 214 m wide, 7.3 m high viaduct underpass that spans a low lying area. Visual and noise-related disturbances from the road with vehicles are likely greater compared to an overpass structure that has similar width. This structure is likely suitable for black-tailed gazelle and Mongolian gazelle, but khulan may not use the structure in acceptable numbers.

5. Underpass 200-300 m wide, 5-7 m high

This intermediate sized overpass is likely to be suitable for black-tailed gazelle and Mongolian gazelle, based on Tibetan gazelle using a similarly wide underpass and several individual gazelles in Israel using a 150 m wide overpass (similar width but different structure type; see earlier). Khulan may or may not use this structure in acceptable numbers. This structure is expected to not be suitable for argali based on a comparison to desert bighorn sheep in Arizona (USA) which mostly use ridges and primarily cross the road using overpasses.

6. Underpass 50-100 m wide, 5-7 m high

This is the narrowest underpass. This underpass will have reduced through visibility and openness compared to 200-300 m or 500-1000 m wide underpasses. It is uncertain how effective this crossing design will be at mitigating fragmentation effects of the road for the four focal species. Visual and noise-related disturbances will be greater with these structures than for overpasses and wider underpasses.

Cost Considerations of Wildlife Crossing Structures

Just as there are a variety of measures designed to mitigate the impacts of roads on wildlife populations, there are a range of costs for these measures. Typically large crossing structures (wildlife overpasses) are more costly than smaller, below-grade passages (wildlife underpasses). The cost of the respective measures is an important factor in planning and decision making. Often the more costly but proven measures are passed over in favor of less costly measures that are less likely to meet performance goals. There is no clear formula for cost estimating standard bridge and culvert work, and estimates for wildlife crossing structures can be even more obscure. There are many factors that can influence the estimated cost of wildlife crossing structures and these are discussed briefly below.

The current proposal for mitigating fragmentation effects of the OT-GS Road upgrade includes at least 16 wildlife underpasses spaced at roughly 6 km intervals (TBC and FFI 2012a). Each underpass has been designed to be of open span design measuring at least 12.0 m wide (road length) and 4.5 m high. The cost estimate for one underpass is reportedly US$5 million. This cost estimate was provided by AMEC in Vancouver, British Columbia, Canada. Although many factors may influence how this cost estimate was obtained, from our experience and knowledge of costs of comparable wildlife crossing structures in North America it is important to discuss this estimate in context of other similar projects and factors that may affect construction costs.

There are a number of factors that can affect the cost of wildlife crossing structures (or bridges) in transportation projects. The driving factors can be divided into three areas: Engineering, Labor and Construction Management and Market.

Engineering considerations include topography, soils, and materials. The type of terrain (topography) and soils can greatly affect construction costs. As a general rule, the more level the terrain the lower the costs, although taking advantage of variable terrain can reduce the size of the structure. Less rocky soil also results in lower costs. High costs are generally incurred when building in rugged and rocky terrain and when blasting is required to remove rock. The proposed wildlife crossing structures on the OT-GS Road are largely in level terrain, however the geotechnical and soil aspects are unknown to us at the moment. The type of construction materials will affect costs and will vary as prices change over time for steel, concrete and other construction materials. The accessibility of the materials used in construction will impact costs. Generally, the more abundant and the closer materials are to the site, the less cost in using them for construction. Design options such as pre-cast concrete or cast-in-place will affect costs, as pre-cast concrete beams and arches may be less expensive than cast-in-place. Overall costs will be lower if pre-casting is done for many beams or arches rather than just a few. Lastly, simple designs will be less costly than complex designs that might require greater construction time and more and/or different materials than those commonly used elsewhere.

Depending on the location and current state of economy, construction labor prices may vary widely. The same is true for construction labor wages in developed vs. developing countries. Market conditions and state of economy can have profound influences on the cost of infrastructure projects. Budgets for projects will be high during “boom” times or active economic growth and can be a fraction of the cost during stagnant economic periods. As an example, when project budgets were created for upgrading the Trans-Canada in Banff National Park, the province of Alberta was in a boom phase. However, by the time bids were accepted and work tendered, Alberta’s economy had stagnated and contract bids were significantly lower than original engineers’ estimates. On the paving contact alone, bids came in at US$ 40 million less than budgeted.

Construction management and market can have an impact on costs. Whether construction firms have experience building crossing structures may have some effect on costing. Inexperienced firms may have higher construction bids and longer schedules to account for delays in construction and risk.

Costs of wildlife crossing structures in North America vary from place to place, largely due to factors explained above. To put the US$ 5 million OT wildlife underpass in perspective with similar projects we present the following projects and crossing structure costs:

1. Banff National Park, Alberta, Canada – Trans-Canada Highway 2010-13 upgrade (2 to 4 lanes) with crossing structures. All three below were built on a 4-lane highway (thus "2" structures) with a 15-20 m wide median. The OT-GS Road project is a 2-lane, 12 m wide highway and should cost less than these projects.
    a. 2 - 12 m wide wildlife underpasses (two separate structures for each two lane with shoulder carriageway with 15-20 m median) in 2013 dollars: **US$ 1.8 to 2 million.** This results in an average cost per structure of US$950,000 and a cost of US$80,000 per meter width of structure.
    b. 2 -22 m wide wildlife underpasses (two separate structures for each two lane with shoulder carriageway with 15-20 m median): **US$ 3.8 to 4 million.** This results in an average cost per structure of US$ 2 million and a cost of US$ 90,000 per meter width of structure.
    c. 2- 60 m wide wildlife overpasses (structure plus landscaping only (excluding roadway) over two separate two lane with shoulder carriageways with 15-20 m median): **US$ 4.8 to 5 million** This results in an average cost per structure of US$ 2.5 million and a cost of US$40,000 per meter width of structure (Parks Canada Highway Service Center, personal communication)
2. Pinedale, Wyoming, USA – 2 lane Highway 191.
    a. 2-50 m wide wildlife overpasses: **US$ 5 million** constructed in 2012. This results in an average cost per structure of US$2.5 million and a cost of US$50,000 per meter width of structure (H.Sawyer, personal communication).

These underpass and overpass cost estimates are in agreement with costs of crossing structures in the following locations:

- Highway US 93 Montana (40 wildlife underpasses, 1 wildlife overpass)
- Trans-Canada Highway, Dead Man's Flats and Canmore, Alberta (2 wildlife underpasses)
- Interstate 90, Washington State, Snoqualmie Pass East Project (4 wildlife underpasses)

Given the costs (estimated and realized) of crossing structures in North America, it would be of interest to know how AMEC arrived at a US$ 5 million estimate for a 12 m wide underpass structure on the 12 m wide OT-GS Road. For that the same cost, two 50 m wide wildlife overpasses were built for pronghorn on a similar sized road in Wyoming. Also for the same costs two 60 m wide wildlife overpasses could be built (in Canada) that span 4-lanes of traffic and a 20 m wide median. The AMEC appears to be over cost by an order of magnitude. On reason for this higher cost may be due to excessive earthwork and paving required for nearly level approach grades. Refer to the section titled Engineering Considerations for a discussion of increasing these grades.

We realize that there are several unknowns with regard to costing the construction of a wildlife underpasses on the OT-GS Road. For example, although labor costs may be less in Mongolia compared to North America, the engineering may be more costly in the Gobi region. Bridge engineers working on the OT Project will have a better idea of the real costs of engineering, labor and construction management. Our estimate of costs for a wildlife underpass or overpass less than 50 m in width is in the range of **US$ 1-2.5 million**. For larger structures we estimate typical costs of **US$ 50,000-100,000 per meter** width of structure.

Our intent in this section is to provide context and discussion for estimating realistic total project costs for wildlife crossing mitigation for the OT-GS Road. We recommend that when engineers are at the technical design stage for crossing structures on the OT-GS Road, that efforts are made to solicit estimates from multiple reputable construction firms with experience designing and building wildlife crossing structures. To that end, we can provide a list of multinational construction and engineering companies with experience designing and building crossing structures in North America, Europe and Asia.

6.3.3 A Phased Approach

Given the uncertainty regarding how the focal species will adapt and respond to crossing mitigation on the OT-GS Road, we recommend a phased, adaptive wildlife crossing mitigation approach. Phasing the installation and subsequent monitoring of the structural crossings is an evidence-based approach to provide the most effective measures to mitigate the fragmentation effects of the OT-GS Road. Rather than design, build and install a suite of 16 (or more) wildlife crossing structures at about 6 km intervals along the 106.8 km of road at one time, we propose to begin with the installation of a subset of the total crossing structures at five sites, placed in the most critical habitat for maintaining connectivity across the OT-GS Road for the focal species.

This phased approach has an important benefit compared to building all crossing structures that might be required all at the same time. The phased approach allows for evidence-based advice for later phases. We propose that the first phase is focused on gaining a substantial amount of information on the performance of different crossing structure types and dimensions. This will result in evidence-based recommendations for the subsequent phases of crossing structure implementation along the OT-GS Road and potentially for other roads and railroads in the Gobi. Once all phases along the OT-GS Road have been completed, the end result is more likely to have effectively mitigated the barrier effect for these desert ungulates compared to an approach where all structures are built at the same time, potentially of the same type and dimensions, and the selected structure type and dimension may be either unsuitable (too small) or over built (larger than necessary). For the first phase we focus on the most critical and auspicious locations for black-tailed gazelle and khulan in the central valley. This maximizes the probability of early success of the mitigation measures and it increases the probability of continued and perhaps even increased support for subsequent crossing mitigation on the OT-GS Road.

Phase 1A Crossing Structures

Phase 1A is focused on gaining substantial information on how well different types and dimensions of wildlife crossing structures allow for road crossings by Khulan and black-tailed gazelle. Phase 1A is located along the OT-GS Road in the central valley. It focuses on the two species for which the barrier effect of the OT-GS Road may have the most severe and immediate consequences: Khulan and black-tailed gazelle. The structures for phase 1A should be located in road sections where khulan and black-tailed gazelle have been observed most frequently on or near the road. This increases the probability that khulan and black-tailed gazelle will at least approach the structures.

There are several approaches that could be implemented in the central valley. There are currently six proposed locations for structures in the central valley, although currently proposed locations need further discussion and finalization. For the phased approach, we recommend starting with sites 7, 8 and/or 9 (Figure 36). Possible approaches seek to balance potential construction cost, implementation time, and the likelihood of providing acceptable permeability for the focal species. Some potential options are summarized below:

- The currently proposed option would dictate building 12 m wide (at a minimum) underpasses at all six sites as soon as possible (TBC & FFI 2011). This would likely have the lowest cost and could be implemented quickly. However, we believe this would have a very low probability of resulting in a road with suitably permeability for wildlife. We believe that this would not be a good use of resources and we do not recommend this approach.
- The ecologically ideal option would be to construct 500-1000 m overpasses at all six sites. Because the “optimal” structure would be constructed at all six sites at once, no monitoring is needed for “future” phases as all structures would be constructed at the same time. However, the design and construction complexity would slow the actual implementation time. This option is very likely to result in a road that has suitable permeability for the target species, but this option is unlikely to be economically feasible.
- A comparative approach option would create a paired comparison (one overpass and one underpass at each site) of three different sizes at three different sites (Figure 36). Because of the cost unknowns (e.g., required blasting for rock if an overpass is used), there is a decision point after design and before construction. If the overpass and underpass of a given size have a similar cost, only the overpass should be constructed. If the overpass is significantly more expensive, the pair should be constructed and monitored to determine if the ecological benefit is worth the extra cost. Regardless, all three sites would be monitored. The results might provide valuable information for optimal crossing structure design for the remaining sections of the OT-GS Road as well as other roads and railroads in the Gobi region. This option is also very likely to result in a road with suitable permeability because the data from the potentially first six structures will result in guidance for the least cost structure that still provides acceptable permeability. This would be more expensive than building three individual structures at the three sites, and it would likely take more time because of the monitoring, but it will likely be less expensive than the ecologically ideal option. We recommend pursuing this option if financial resources are sufficient to allow for this approach. It would still be

worthwhile to implement a pairwise comparison for only the smallest (50-100 m wide underpass and overpass) and medium structures (200-300 m wide underpass and overpass), or only the smallest structures (50-100 m wide underpass and overpass) if insufficient funds are available for the construction of the largest structures (500-1000 m wide underpass and overpass) or for both the largest and medium structures.

- If the comparative approach option is not financially feasible, an adaptive management approach could be implemented, starting with small structures at two sites and gradually increasing the size at additional sites if monitoring shows the small structures do not result in a road with suitable permeability for the focal species.

Balancing fiscal and ecological considerations, the comparative or adaptive approaches are most likely to be both economically feasible and make the OT-GS Road suitably permeable (Table 5). The consideration for the time it takes to fully implement an approach is also an important consideration when choosing between the comparative or adaptive option. The comparative option requires a larger investment up front to implement but might allow a better understanding of the optimal structure type much sooner. Both of these options are described further below and provide a general approach. Lastly, OT may also opt for an implementation approach, in terms of the order, type and location of structure construction, that is a combination of the approaches described in Table 5.

Table 5: Comparison of Implementation Approaches.

Approach	**Time to Implement**	**Cost**	**Permeable to target species**
Currently Proposed	Short	Low	Very Unlikely
Ecologically Ideal	Medium	Very High	Very Likely
Comparative	Medium	Medium to High	Likely
Adaptive	Long	Low to High	Likely

If the comparative approach is selected we recommend that for phase 1A a total of six crossing structures are constructed at three sites. The six crossing structures consist of two different types and three different dimensions (Table 65).

Table 6: Phase 1A Structure types, dimensions, and number proposed.

Structure Type	Range for structure width (road length) (m)	Range for structure height (m)	Number to be built in phase 1A
Overpass	500-1000	*	1
Overpass	200-300	*	1
Overpass	50-100	*	1
Underpass	500-1000	5-7	1
Underpass	200-300	5-7	1
Underpass	50-100	5-7	1

* No height dimension for wildlife overpasses.

Phase 1B Crossing Structures

The following three sites can be constructed as soon as possible, but we recommend prioritizing the construction of the structures listed for phase 1A. If construction of the following three sites does not hinder or slow down the construction of the structures listed for phase 1A, the two structures and additions to site 1 listed for phase 1B can be constructed at the same time.

Underpasses should not be constructed in this region as overpasses are much more suitable for Argali. Taking advantage of natural terrain will likely make overpasses less costly than underpasses in this area and will also be more likely to be used by Argali.

- Underpass 10 m wide, 4.5 m high, Mitigation site 1: This is an underpass, currently under construction, which was primarily designed for hydrological reasons (Figure 378). While some wildlife species may use this structure also, we do not expect this structure to be suitable for the focal species. The structure is situated in a dry wash at the northern end of the road and is expected to be completed in 2013 or at the latest by 2014. This underpass is currently not expected to be paired with another crossing structure, but we recommend the structure to be included in a monitoring effort once it is completed. We also recommend that structure attributes (e.g. fencing, visual barriers, barriers for vehicles, drive lines, water etc. (see later)) are similar to the structures that are part of phase 1A.
- Overpass 50-100 m wide, Mitigation site 2: Argali have been observed on and near the road at this location. It is a ridge, which appears to confirm that argali may move similarly through the landscape than desert bighorn sheep in Arizona (USA). We recommend a 30-60 m wide overpass for argali. However, since black-tailed gazelle have also been observed near this

mitigation site, we recommend increasing the width of the overpass to a width that might also be suitable for black-tailed gazelle (50-100 m). Khulan are relatively rare in this area; therefore, we do not recommend designing a crossing structure at this location for khulan. This overpass is currently not expected to be paired with another crossing structure, but we recommend the structure to be included in a monitoring effort once it is completed. We also recommend that structure attributes (e.g. fencing, visual barriers, barriers for vehicles, drive lines, water etc. (see later)) will be similar to the structures that are part of phase 1A.

- Overpass 50-100 m wide, Mitigation site 3: This site is also located on a ridge and we expect argali to cross the road at this location too. Similar to mitigation site 2, we expect black-tailed gazelle to also potentially use the crossing structure, justifying a slight increase in the recommended width of the structure from 30-60 m to 50-100 m).

Figure 37: Bridge (about 10-12 m wide) under construction on road section from Oyu Tolgoi (mine site) to Gashuun Sukhait (border Mongolia/China), Gobi, Ömnögovi, Mongolia (© Marcel Huijser). This bridge is designed for water that may flow here after rare rain fall. The structure may also be used by wildlife under certain circumstances.

Phase 1A Study Design and Mitigation Site Selection for Comparative Option

Given the lack of data regarding the type and dimensions of wildlife crossing structures that may be suitable for the focal species, we recommend adopting a comparative approach to the initial phase of construction (phase 1A). The results of this study will guide subsequent mitigation recommendations. Some of the most compelling data and arguments for specific crossing design use have arisen from side-by-side comparisons of two crossing structures of varying design. Two paired overpass vs. underpass comparisons in Banff National Park and Wyoming have yielded results that have largely surpassed what can be learned from monitoring of single, isolated structures (Clevenger et al. 2009; H. Sawyer, personal communication).

The recommended comparative study design includes three locations (crossing locations 7, 8 and 9, Figure 35, Table 7), each location with two crossing structures. Each location will have an underpass and an overpass of similar width. The distance between the two structures at each location should preferably be only a few hundred meters up to perhaps 1000 m. The road section between the two neighboring structures will have continuous visual barriers, wildlife fencing and barriers designed to keep vehicles on the road. The premise is that wildlife species that approach the paired structures will have a choice; use the underpass, use the overpass, or turn back. We strongly recommend similar attributes (e.g. fencing, visual barriers, barriers for vehicles, drive lines, water etc. (see later)) for all crossing structures. Since the width of the underpass and overpass is also similar, the only consistent difference between two paired structures is their type (underpass vs. overpass), and the only consistent difference between the structures at the three locations is their width (50-100 m, 200-300 m, 500-1000 m).

The three locations recommended for the crossings structures in phase 1A are all located in the central valley. The three locations are based on the proposed locations for wildlife underpasses by OT (Figure 35). These three central valley locations appear to the most optimal location in the entire study area for siting crossing structures for khulan and black-tailed gazelle. Wildlife mitigation site #8 is likely the most suitable location for khulan crossings and for that reason we suggest that site for the largest overpass and the largest underpass. This is the location where we have at least some evidence that khulan are likely to come close to the road in relatively high numbers, and where they are potentially interested in crossing it, again, in relatively high numbers. It makes sense to provide the most inviting structures at a location where we may expect the most sensitive species (khulan). Similarly this reduces the risk that the largest and most expensive structures are constructed at a location where they may not serve khulan very much and where the structures may not generate much data.

The locations for the other two wildlife crossing structure pairs should also be located in the central valley that is most likely to be used by khulan and black-tailed gazelle. The terrain should also be similar (i.e. very flat) compared to mitigation site location 8, where the largest underpass and the largest overpass are proposed. While khulan and black-tailed gazelle movements through the central valley and across the OT-GS Road may be close to random, there is at least some evidence that mitigation location 7, 9 and 10 also have khulan come close to the road. Therefore we recommend picking one of these three locations for the medium sized underpass and the medium sized overpass, and one of the remaining two locations for the smallest sized underpass and the smallest sized overpass. The choice may be influenced by how suitable the three mitigation sites are for the construction of differently sized underpasses and overpasses.

Table 7: Wildlife crossing structure paired tests at four mitigation sites on the OT-GS Road.

Mitigation site location*	Crossing structure type and dimensions	Dimension class
8	Overpass 500-1000 m vs. underpass 500-1000 m	Large vs Large
7 or 9 or 10	Overpass 200-300 m vs. underpass 200-300 m	Medium vs Medium
7 or 9 or 10	Overpass 50-100 m vs. underpass 50-100 m	Small vs Small

*Crossing structure location based on proposed locations for wildlife underpasses by OT (see Fig. 36).

Phase 1A Study Design for Adaptive Approach Option

In general this approach involves starting with constructing relatively small structures, conducting monitoring and then increasing the structure size for other locations if necessary based on monitoring results. A potential timeline is shown in Figure 39.

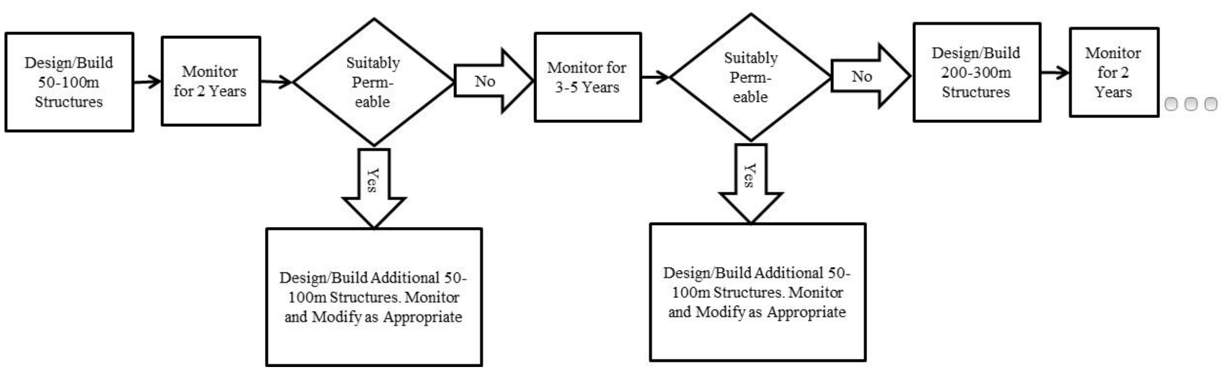

Figure 38: Adaptive Approach Option.

This approach starts with constructing one or more 50-100 m structures in the central valley area. The initial construction should include both an underpass and an overpass, ideally at the same site. As discussed in the comparative approach, this paring provides the best possible answer to the question whether overpasses or underpasses are better suited.

The initially constructed structures could see significant use by wildlife in the first year or two. If this is the case, structures of similar size and design would be constructed at other sites. If significant use is not seen, it could be that the wide ranging khulan and gazelle are simply not in this particular area during this time period. In this case, it may be appropriate to monitor for more years to verify that the structure type is not appropriate. If the 50-100 m structures prove to be ineffective at providing suitable permeability, the next step would be to build one or more 200-300m structures and continue the adaptive process in Figure 39.

This approach would likely result in the optimal implementation of the type and size of structures that will be least expensive while providing suitable permeability for the OT-GS Road. The downside is that it is a slow approach with possibly numerous monitoring periods. In addition, there is the risk that the smallest and perhaps least suitable structures are constructed at the locations where black-tailed gazelle and khulan approach the road in the greatest numbers. Better suited structures may be constructed elsewhere with lower abundance of the target species.

Again the comparative and adaptive approaches are provided as a starting point. We recommend the comparative approach, based on the commitment to net positive impact and our perception of the need for timely progress. We realize that the final decision on the approach is made by OT and other project partners based on ecological performance as well as fiscal and time constraints.

Phase 2 Crossing Structures

This second phase of crossing structure installation will build upon the information obtained from the crossing structures built in phase 1A, and potentially also from those built in phase 1B. Phase 2 will focus on building additional crossing structures, primarily in the central valley and primarily for khulan and black-tailed gazelle. However, additional structures may also be recommended for the granitic outcrops between the mine site and the central valley. These structures will most likely be designed for argali and black-tailed gazelle.

Here we only provide general guidelines for the phase 2 crossing structures based on available information and our recommended approach to mitigating fragmentation effects of the OT-GS Road upgrade.

- We currently do not have sufficient data to evaluate the proposed number (16) and spacing (6 km) between the proposed crossing structures. However, we do encourage being flexible with the number and spacing based on new information that is likely to become available within the next few years.
- When siting underpasses, if (seasonal) riverbeds are present they should preferably be placed at these riverine areas so that two functions (hydrology and wildlife passage) can be combined in one structure. Dry riverbeds may also be followed by desert ungulates as

they are linear features and a source of water (khulan often dig holes in dry river beds to access ground water).

- The type and dimensions of the recommended crossing structures for phase 2 should preferably be based on the outcome of the monitoring efforts associated with phase 1A and 1B.

6.3.4 Crossing Structure Attributes for Wildlife Underpasses and Overpasses Along the OT-GS Road.

The following three general recommendations should be incorporated into wildlife crossings at each wildlife mitigation site along the OT-GS Road, at least the ones listed for phase 1A and if possible also for phase 1B. These recommendations seek to minimize variations between the mitigation sites and between the individual crossing structures.

- General recommendation 1: Keep the design features (i.e., fencing, barriers) the same at each wildlife underpass and overpass for phase 1A to minimize variation between the structures in phase 1A. Phase 1A (at least the comparative and the adaptive management approaches) is designed so that the suitability of the different types and dimensions of structures for khulan and black-tailed gazelle can be evaluated. Varying design for other parameters such as barriers for vehicles, wildlife fencing, visual barriers or other attributes would introduce variation, which makes it difficult or perhaps even impossible to draw conclusions on what type and dimensions of structures would be most suited for khulan and black-tailed gazelle.
- General recommendation 2: If uncertain which design for barriers for vehicles, wildlife fencing, visual barriers, drivelines or other attributes should be implemented, conduct tests away from the wildlife underpasses and overpasses and select one “winning design” that is implemented at all wildlife underpasses and overpasses.
- General recommendation 3: implement the integrated barriers for vehicles and people, wildlife fencing, and visual barriers for 500 m on each side of a wildlife underpass or wildlife overpass on both sides of the road. If neighboring wildlife underpasses and overpasses are within 2 km from each other, especially if they are a pair at a particular mitigation site (see phase 1A), implement the barriers/fencing/visual barrier without any gaps between the structures.

Vehicle Barriers

These barriers are needed to discourage vehicles from leaving or accessing the road.

Recommendations:

- Implement barriers at each wildlife underpass and wildlife overpass listed for phase 1A and 1B.
- Barriers that discourage vehicles from leaving or accessing the road are suggested only in the immediate vicinity of safe crossing opportunities.
- Continuous barriers that discourage vehicles from leaving or accessing the road are suggested in areas that have a concentration of safe crossing opportunities (e.g. less than 2 km apart).
- Integrate barriers in a structure that also functions as a wildlife fence and/or visual screen (see later, also for recommended distance from a structure).
- If a visual screen is not required (e.g. if road is lowered and out of sight already close to a wildlife overpass), then integrate these barriers in a structure that also functions as a wildlife fence.

Wildlife Fencing

- Unless the visual barrier alone can act as a wildlife barrier, use mesh wire fencing or chain-link fence with visual barriers such as fabric, plastic slats, or plastic mesh.
- The fencing should be about 2.4 m high at a minimum, but if the visual barrier needs to be higher (based on truck visibility for the animals), then the wildlife fence can be higher too if that benefits the design. Note that while the livestock fencing along the Trans-Mongolian railroad is considered a very substantial barrier to khulan and black-tailed gazelle, Mongolian gazelle do cross this low fence and get entangled in it. Therefore, the wildlife fencing along the project road should be higher and of a different design than the livestock fence along the Trans-Mongolian railroad.
- Fabric attached to fencing or posts will most likely deteriorate and rip apart with the sun and wind in the Gobi. Wood material may be removed by people for fuel. The visual barrier may create sand dunes. We recommend installing a test section of the fence and visual barrier to identify any potential fatal flaws.

Visual Barriers

- Consider integrating visual barriers with wildlife fencing and barriers designed to keep vehicles and people from leaving the road. A good option may be the W310x21 panels proposed in the draft wildlife overpass plans developed by AMEC. These are 5 m tall and would (1) block visibility of the traffic to animals, (2) provide some sound barrier,

(3) restrict wildlife from crossing the road, (4) restrict vehicles from leaving road and (5) would be visible to birds. There may be better options for visual barriers that do not act as wildlife barriers and would require separate fencing. For example, a wildlife overpass could have an earth berm to hide traffic from the animals and provide some noise barrier, with a fence running parallel to restrict wildlife movement and vehicles leaving the road. The best option should be chosen based on cost, available materials, maintenance, etc. so long as the fencing and visual barriers combine to accomplish the five requirements above.

- The visual barriers should be designed to blend into the surrounding landscape. The barriers should be tall enough to hide the vehicles that travel the road frequently. The tallest trucks may be those that haul the concentrate from the OT mine site to the border. The height of the visual barrier may be the height of the trucks, unless the ground level at the location of the visual barrier is lower or higher than the road surface.
- The material for a visual barrier could be concrete or brick, or lighter weight solid material. Care must be taken though that the material can withstand high and low temperatures, UV radiation and high winds. Wood may not be suitable as wood is in high demand as fuel in the region and locals may simply remove any wood material. Earthen berms may require a huge footprint over which the soil is scraped, especially if the earthen berm is to reach the height of the trucks.
- If integrated with barriers for people and vehicles and wildlife fencing, a visual barrier could perhaps be as simple as a mesh wire fence with metal posts and PVC strips woven into the meshes of the fence. This type of fence may not be visually appealing, but it may be functional and stand up to the elements.

Noise barriers

- Noise barriers may require:
  - Substantial berms (and substantial soil impact because of material needs to build these berms)
  - Walls, potentially arched back towards the roadway. These may be tall concrete barriers.
- Integrate visual barriers with wildlife fencing, visual barriers, and barriers designed to keep vehicles and people from leaving the road.

Drive Lines that Funnel Ungulates to Wildlife Underpasses or Overpasses.

Historical drive lines that were designed to funnel wildlife movements in order to concentrate, trap, and kill them are discussed in Section 5.6. In the context of highway mitigation measures for wildlife, these drive lines can perhaps also be used to encourage wildlife to approach the road where wildlife underpasses or wildlife overpasses are present. This may be especially important in areas where wildlife fences are not constructed or are only constructed for short distances in the immediate vicinity of wildlife underpasses or overpasses. There are several types of drive lines that can be considered:

- Cairns
- Stone walls
- Berms and ditches
- Lines of rocks

Specific dimensions were not available for all drive line designs. Our recommendations are the following:

- Implement drive lines at each wildlife underpass and wildlife overpass listed for phase 1A and 1B. Keeping the "attributes" the same at each wildlife underpass and overpass minimizes variation between the structures in phase 1A and 1B so that important data can be obtained on the suitability of the different types and dimensions of structures for khulan and black-tailed gazelle.
- Drive lines for Tibetan antelope are perhaps most applicable to black-tailed gazelle and khulan in the Gobi, as these drive lines do not appear to have been dependent on humans driving the animals from behind or humans hiding behind the drive lines. Lines of rocks or cairns (perhaps 30-50 cm high (Huber, 2005)) would also not disturb the surrounding soil, hydrology and vegetation as much as berms or ditches would. If cairns are used rather than lines of rocks, the interval between the cairns can be perhaps 2-3 m at the furthest point from a wildlife underpass or wildlife overpass. The interval may be gradually reduced towards the structures, ending at about 50 cm interval (Huber, 2005).
- The angle of the lines of rocks or cairns relative to the road is up for debate. The researchers suggest 45°. The length of the lines of rocks or cairns should perhaps be 1000 m. This would extend beyond the zone adjacent to the road that the desert ungulates may avoid. With 1000 m long drive lines at 45° from the road (ignoring that the drive lines may start at the edge of the under or overpass rather than at the center), the mouth of the funnel would be 1414 m wide. However, the drive lines may also be set back from the edge of the structures so that animals may move along both sides of the drive lines.
- Have the cairns or lines of rocks continue inside an underpass or on top of an overpass. The rocks may provide cover for small mammals and reptiles, and encourage these species groups to use the wildlife crossing structures.

Soil and Vegetation

Recommendations:

- Implement substrate (soil) on wildlife overpasses and at wildlife underpasses that is similar to the surroundings. Seed or transplant native species that are also present in the immediate surroundings of the structures. Conserve topsoil, set it aside during construction and use it on top of wildlife overpasses and inside wildlife underpasses (unless the soil was not removed or disturbed at an underpass to begin with). Implement substrate on wildlife overpasses and at wildlife underpasses that is similar to the surroundings.

- For grass-herb vegetation, a soil depth of at least 30 cm has been recommended (Kruidering et al. 2005). It is uncertain if this soil depth would suffice in an arid climate as the Gobi. We recommend using the root depth of the most common grasses and herbs in the vicinity as an indicator to perhaps consider increasing the soil depth beyond 30 cm. Soil depth has important consequences for the structural load of wildlife overpasses.
- There may not be sufficient light or moisture inside underpasses for vegetation, but restore vegetation where it can grow.

Water source and/or irrigation

Providing a water hole (or removable water tank) on either side of a crossing structure is a common phenomenon (Kruidering et al. 2005). In an arid environment such as the Gobi, a water source would likely be a strong attractant to the desert ungulates, potentially increasing the likelihood that they will approach and use the structures. Livestock is also likely to use the water source. We think use by livestock may simply have to be accepted. If the wild ungulates actively avoid the water holes because of domestic livestock, then domestic livestock either has to be excluded from using the water holes or the water holes should no longer be provided. Alternatively tanks may be (temporarily) removed while livestock is present.

Recommendation:

- Provide a water source for the desert ungulates on both sides of each structure, potentially at a distance of half the width of the structure, but not on or under the road (perhaps 50-100 m away from the road).
- Considerations: if providing water is considered too much of an attractant to wildlife or if it makes desert ungulates too vulnerable to poaching because they spend substantial time near the road, perhaps do not provide water.

The Gobi region has high inter-annual variability of precipitation (39%) and episodic droughts (Begzursen et al. 2004). Such characteristics lead to the desert-steppe zone of the Gobi exhibiting many characteristics of non-equilibrium rangeland vegetation dynamics (Fernandez-Gimenez and Allen-Diaz 1999). A review of five meteorological stations' data across the region between 1970-2006 indicates droughts in parts of the Gobi that lasted in excess of 19 months (over two growing seasons) during this time period (Sternberg et al. 2011). As a result of sporadic and episodic rainfall, native herbivores, such as Mongolian gazelle, have been shown to migrate and follow green pasture, especially for calving grounds and wintering areas (Leimgruber 2001). Such an attraction to "greenness" by native ungulates could be advantageous to the testing of the wildlife crossings.

It would perhaps also be conducive to create artificial rain events on either side of the crossings to increase the probability that the four focal species approach and use the phase 1A wildlife crossings structures. By utilizing a water truck with a boom, patches of adjacent vegetation on both sides of a crossing would receive 25-50mm (~1-2 inches) of water in a single day. This would mimic a natural rainfall event and would create green to attract focal species to the area immediately adjacent to each of the crossings. Similar to water sources, these strips are also likely an attractant to livestock. If the watering treatment results in overgrazing by livestock and is not an attractant to wild ungulates, then abandon this approach.

Recommendations:

- Water a strip (perhaps 50 m or 100 m wide, or perhaps simply the width that a truck with a water spray installation can cover) from the center of each crossing structure, at perhaps 60° from the road (well inside the funnel created by the drive lines) on each side of the structure. The strips (4 per crossing structure) could perhaps be 1000 m long, consistent with the drive lines.
- Each strip at each crossing would receive one watering event per year, about one month before highest abundance of khulan or black-tailed gazelle would be expected close to the road and the crossing structures (if there is indeed any temporal pattern). Alternatively, since most rainfall is concentrated in the summer months (Retzer & Reudenbach 2005), any time in June, July or August would be consistent with natural precipitation patterns and boosting natural production in the vicinity of the structures.

Openness Required for Focal Species

Recommendation:

- Preserve the openness and long view distances across overpasses or through underpasses. It is essential that underpasses have no or minimal support pillars as they affect the openness and the view distances and can therefore jeopardize use by wildlife. If support is needed inside an underpass, use pillars rather than solid support walls. Nonetheless, the distance between support pillars should be dozens of meters at a minimum, and preferably much longer. This is a critical requirement and if distances between rows of pillars are short or if solid walls rather than pillars are used it is likely to have a substantial negative effect on the use by the desert ungulates. It is essential to work with contractors who are able to build underpasses with long distances between support pillars. If the material or skill for such construction is not available in Mongolia, consider hiring foreign companies and instructors. The main work force could still be Mongolian, but after the OT project is done the Mongolian work force would be trained with regard to building larger span structures and have appropriate material for road construction projects elsewhere in Mongolia.

- Remove unnatural objects that are not associated with the wildlife crossing structures, especially potential construction debris and unnatural objects that may cause ungulates to reject the crossing structure.

6.3.5 Engineering Considerations

Justification for 6 percent grade

We would encourage OT to obtain a design exemption on the maximum grade. Although not verified, it seems there was a maximum two percent grade used as a design standard for the OT-GS Road. There is good reason for this. With a large percentage of the traffic being heavily loaded trucks, grades can have a major impact on the performance of the roadway. A typical heavily loaded truck (a weight power ratio of 120 kg/kW) can maintain speeds of nearly 80 km/h on a continuous 2 percent uphill grade. A continuous 8 percent grade will quickly slow trucks to slightly less than 30 km/h crawl speed.

The initial sketch design of the wildlife underpass was completed with the requirements of maintaining a level path for the animals, and not exceeding a maximum grade for the vehicles. To maintain 4.5 m below the structure, the road surface needs to be raised an estimated 6.6 meters above the natural ground. Under some basic assumptions (e.g., minimal vertical curves, 2:1 side slopes, flat terrain), this results in approximately 670 m of reconstructed road and 43,000 m^3 of fill material for each crossing structure (including both sides of the structure). Although higher grades will slow trucks down, this would only be for a short segment, with a downgrade directly following to help the trucks regain their speed. Keep in mind that the total elevation gain is only 6.6 m. With the visual obstructions and narrow bridge, it may be advantageous from a safety perspective to slow trucks down anyway.

By comparison, a six percent grade would achieve the 6.6 m rise in only 110 m. This grade would reduce a typical heavily loaded truck by about 7 km/h (AASHTO 2011). This results in less than one extra second of travel time. The six percent grade results in about one third of the earthwork and paving needed (Table 88). A cursory review of the engineer’s cost estimate reveals that at least 80 percent of the cost of the animal crossing structures is earthwork and paving (the rest being related to the bridge structure, which would not be reduced by a steeper grade).

Table 8: Cost comparison of grades of 2 and 6 percent with a level grade.

Option	Estimated length of road reconstruction (m)	Estimated volume of fill (m^3)
2% Grade	670 m	43,000 m^3
6% Grade	230 m	14,300 m^3
Cost Reduction	66 percent	68 percent

Recommendations:

- OT engineers are encouraged to revisit the maximum grade guidelines/standards used in design and consider a six percent grade for use to raise or lower the road at the wildlife crossing structures.
- For wildlife overpasses, the road should be lowered and for wildlife underpasses the road should be raised. This will allow the animals to see across or through to the other side of the structure. OT engineers should verify that raising or lowering the road will not result in an excessive increase in cost, but keeping the slope for the animals approaching the structures at or close to 0° is very important to the use we expected from the desert ungulates.
- Wildlife overpasses wider than 50 m may require lighting for vehicles entering the tunnel and those wider than 250 m may require ventilation, emergency egress and other amenities typically included in roadway tunnels. Though not as optimal as a continuous overpass, one could consider allowing for gaps in the tunnel every 250 m minimizing amenities and maintenance. This would invalidate a direct comparison to the underpasses though.
- Wildlife underpasses should have a vertical clearance for wildlife of at least 5 m, preferably 7 m. The structural design used must achieve this height requirement and the width requirements detailed previously. There are a variety of structural types that have been used in both overpasses and underpasses. OT engineers or consultants, familiar with materials and methods best suited for the region, are encouraged to use the most efficient method.

Structure Type and Road Geometry Considerations

Numerous terms are used for wildlife crossing structures. Further, the terms may have different meanings to different people. A tunnel could mean that the road is buried, or that the wildlife must pass through a long culvert. For this discussion structure types have been categorized into two broad categories: wildlife overpasses and wildlife underpasses. A further characterization can be made based on whether the road is raised or lowered. As shown in Figure 39, there are four basic types of structures:

- For a typical wildlife overpass, the roadway follows the natural grade and the animal must go up and over the structure.
- For a wildlife overpass with a lowered road, the animal's path is level or nearly level (estimated to be optimal for species in open and flat landscapes). When standing on natural ground on one side of the structure, even when some distance away, the animal can see all the way across the structure to the natural ground on the other side. As discussed later, when constructing the road and overpass at the same time, it seems reasonable to create a road cut intentionally for the purpose of creating a structure of this type where the animal's path is level.
- Typical wildlife underpasses require the animal to travel down, below the surrounding terrain, to cross under the roadway. They often take advantage of natural drainages so that the animal's path technically is on natural ground, but it is in a naturally low spot compared to the surrounding terrain.
- Wildlife underpasses with a raised roadway consist of an elevated road bridge over the natural ground (estimated to be slightly less optimal for species of open and flat landscapes than a wildlife overpass that does not require animals to walk up or down a slope when approaching a structure). For these types of structures, the animals from some distance away, must be able to see, not only the ground on the other side of the roadway, but also the horizon under the structure (similar to wildlife overpasses with a lowered road).

For desert ungulates and other species that inhabit open and flat landscapes, we strongly recommend keeping the slope for animals that approach the structures to 0° or close to 0°.

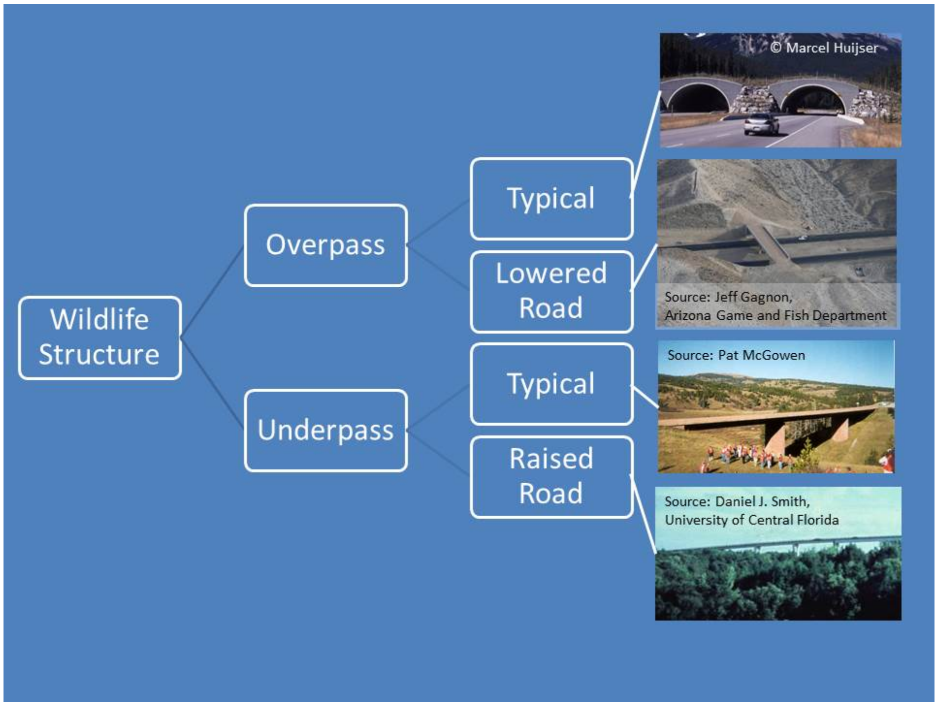

Figure 39: Wildlife Crossing Structure Categories

Beyond these categories, these structures are also defined by width (in terms of the width of the animal's pathway or the length of the road; not the width of the roadway). A wildlife overpass can be wide enough to become a roadway tunnel. For the overpass structures considered here, the top of the overpass consists only of the structure and a minimum amount of topsoil or other appropriate material; therefore, boring as a construction method would not be as cost effective as creating a road cut. Thus, whether or not the road is lowered, the same basic types of structures can be used for wildlife overpasses. The only change would be the approach ramps for the animals on either side of the structure. As far as the structural design, any of these types could include culverts, single span bridges, bridges with piers, etc. The exact structural design is left up to OT engineers and their engineering consultants that are familiar with materials and construction methods that are most cost effective for the region.

As a template for wildlife overpasses, consider the overpasses constructed for pronghorn near Pinedale, Wyoming U.S. on highway 191 (Figure 40). The key suggested elements are highlighted in the figure. The width of this structure is approximately 50 m. The same basic design could be used for wider or narrower structures (although see Roadway Tunnel Considerations for widths over 50 m). On one side the top of the structure nearly matches the height of the existing ground due to an existing rise in the natural ground and road cut. On the other, an earth ramp (6:1) was built up to provide a gentle sloping access to the structure. The Pinedale example shows that a lowered road is feasible. Although continuous fencing along the roadway was used for the Pinedale site (19 km), a shorter length of wing fence is recommended for the OT-GS Road. Guardrail should be used at bridge abutments for driver safety. The Pinedale overpass cost about $2.5 million (USD) for construction.

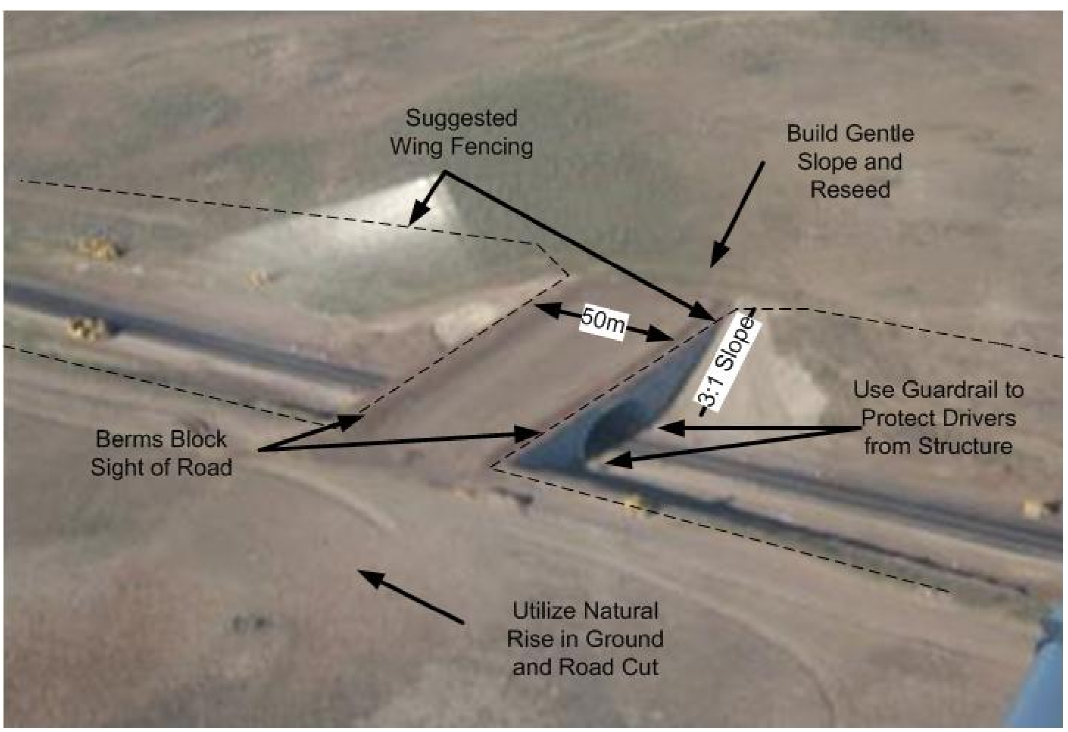

Figure 40: Wildlife Overpass Near Pinedale, Wyoming, USA. (Photo Source: Joe Riis)

For wildlife overpasses, blowing sand could accumulate on the roadway underneath the structure. The need for sand fences upwind of the structure should be considered.

For wildlife underpasses, the typical design is not suitable for the wildlife species considered here. If wildlife underpasses are used on the OT-GS Road, the roadway must be raised. Although single span is preferred ecologically, when piers are used, they are typically spaced far enough apart that they are not a physical barrier to wildlife but they can severely affect the openness of the structure and thereby affect wildlife use. Because traffic is still in view of the wildlife, visual barriers should be used to hide traffic. Guardrail should be used to protect vehicles from running off of the bridge structure. Wing fencing is recommended.

Comparison of Flat vs. Lowered Roadway

The same essentials of the Pinedale design could be used for the typical wildlife overpass, or lowering the road so that wildlife crossing structure was flat and level with surrounding terrain. The volume of extra soil needed (fill material) with a raised wildlife crossing structure could be more than the volume of soil that would have to be removed (cut material) if the road was lowered. A simplified calculation of earthwork was done with the following assumptions.

- A slope of three to one (33.3 percent grade) is typically the maximum desirable slope for areas next to the roadway. This slope is flat enough for maintenance vehicles to be able to access roadside features.
- It was assumed that the ramp for wildlife to climb up to the structure is five to one (20 percent grade). A flatter grade is probably desirable for the target species. A 6:1 grade was used at an overpass for pronghorn in Wyoming.
- It was assumed the road pavement and ditch could fit within a 12 m width trench.
- The structure height was assumed to be 7 m (5 m clearance, 2 m structure).
- The top of the structure will have a width of 50 m (see Figure 40 above).
- A six percent roadway grade was used for the vehicle approaches to the structure.

Based on these assumptions, the volume of fill material needed for a raised structure (48,900 m^3) would be about twice the volume of cut material for a level structure with a lowered road (23,000 m^3). This is largely due to the fact that the roadside cut slope can be much steeper than the earth ramp allowing animals to access the overpass. Note that this reduction in volume may not mean a reduction in cost for the lowered roadway, because a cut slope may require blasting and would be more expensive per cubic meter. If a two percent roadway grade was used, the cut volume is nearly as much as the fill (45,900 m^3 of cut). The pros and cons of a lowered road with a level structure for the animals are:

- There is likely less total volume of earthwork.
- By creating a low point in the road with no area for water to run off, a potential drainage issue is created and would need to be addressed.

- Because the road is below the level ground, vehicles are hidden from view for some distance on either side of the structure. A berm at the catch slope would further hide the vehicles and be less costly than other visual barriers being considered.
- Most importantly, wildlife would be able to see across the structure making it more likely for them to utilize the crossing.

From an ecological perspective, an overpass with a lowered roadway is the preferred option.

Roadway Tunnel Considerations

When a wildlife overpass reaches a certain width (or from the roadway perspective the tunnel length), additional features are required that may significantly increase the cost. For the remainder of this section, size of the structure will be in terms of the tunnel or road length, which is equivalent to the wildlife overpass width. When a wildlife overpass becomes a roadway tunnel the following elements are needed:

- Lighting
    - Backup lighting
- Mechanical Ventilation
    - Fire emergency mode recommended
- Surveillance system including
    - Traffic flow monitoring
    - Air quality monitoring
    - Ability to restrict traffic if near capacity
    - Ability to communicate unsafe conditions to motorists
    - Emergency response
    - Preferably visual monitoring of entire tunnel systems
- Fire resistant structure
- Emergency egress
- Auxiliary lanes for emergency vehicles and evacuation

Clearly the increased complexity has the potential to significantly increase the cost. In addition to construction cost, the annual operation and maintenance cost could be burdensome to the Mongolian government once the ownership of the OT-GS Road is transferred. The exact tunnel length when these elements are needed is not clear cut. Lengths up to 50 m do not require these elements. Lengths over 1000 m typically require all of the above elements. Some thresholds for certain elements are discussed below.

Lighting is required at the tunnel ends to allow for drivers to transition from light to dark without losing sight of the road and other vehicles. This lighting is only needed in daytime, although emergency lighting should be available for stranded motorists exiting the tunnel on foot. No lighting is needed for tunnels with length to height ratios of less than ten to one (around 50 m). Tunnels up to 122 m may not need lighting if they are straight and level (Oyenuga, 2004).

Ventilation is needed in long tunnels to minimize the buildup of noxious gasses from vehicle exhaust. Vehicles moving through the tunnel create some ventilation naturally. As Maevski (2011) states: “Because of the number of different parameters that interfere in the choice to ventilate a tunnel or not (length, location, traffic, type of vehicles using the tunnel, and so forth), it is not possible at this moment to express universal recommendations about the limits of the natural ventilation, especially the allowable length without mechanical ventilation.”

Maevski reviewed several national standards for ventilation. Maximum lengths for which mechanical ventilation is not required are:

- 200 m - Switzerland
- 250 m - Norway
- 300 m one-way tunnel - UK
- 250 m - Netherlands
- 240 m - US

For lengths greater than those listed above, an air flow analysis is required. There are some maximum lengths at which mechanical ventilation will always be required:

- 300-1,000 m depending on traffic volumes - France
- 500 m - Netherlands
- 1,500 m - Japan

Many of the fire, surveillance and egress requirements are typically considered once mechanical ventilation is needed. Based on this information, the following categories are considered:

- Very narrow wildlife overpasses (<50 m wide (road length)) require no additional tunnel related elements (cost US $1-2.5million)
- Narrow and medium overpasses (50 to 250 m wide (road length)) may require some additional tunnel related elements (cost US $50,000 to 200,000 per meter).
- Large overpasses (>250 m) likely require all additional tunnel related elements (cost US $100,000 to 200,000 per meter plus operations).

Costs are based on a cursory review of construction examples in the literature. If large overpasses are not feasible due to the issues discussed, a potential option is to keep the roadway lowered and have alternating sections of tunnel (wildlife overpass) and no tunnel; basically intermittent openings to the sky.

Summary:

- We suggest that the six phase 1A wildlife crossing structures for the comparative approach be designed as soon as possible and that at least one structure be built at each of the three sites.
- The phase 1B wildlife crossing structures (and features added to the 10 m bridge currently under construction) could be constructed at the same time as the phase 1A structures, so long as it does not slow down the phase 1A progress.
- Phase 1A structures should have nearly identical features. These features should include visual barriers and wildlife barriers (e.g., fencing) for 500 m of either side of the structure. When two structures are within 2 km, the barriers should be continuous between the structures. Features should also include drive lines to funnel wildlife, soil and vegetation, and wildlife baiting with water. Openness providing long view distances across the structures is a must.
- A monitoring plan for the phase 1A structures should be developed.
- Phase 2 will be informed by monitoring of the phase 1A structures.
- Phase 2 will include additional structures in the granite outcrop zone and central valley zone based on the latest information.
- Work could begin on an integrated wildlife mitigation plan for all transportation infrastructure in the Small Gobi B strictly protected area (OT-GS Road, Energy Resources road, two track road paralleling the Energy Resources road, and the planned future railroad).
- Phase 3 structures for the Small Gobi B strictly protected area should not be implemented without an integrated wildlife mitigation plan for all transportation infrastructure in this area.

7 SUMMARY OF RECOMMENDATIONS

We reviewed available documents and literature (refer to list in Appendix A and literature referenced in this report), visited the OT mine site and surrounding OT roads in February, 2013, and had numerous discussions with experts in the region and OT staff and consultants. This, with the team's prior expertise in mitigating wildlife impacts of roadways, was used to develop this report. The report contains a summary of the current status of wildlife impacts of the OT roads and planned mitigations (Chapters 1-4), a review of the most promising mitigations and mitigations previously proposed for the OT roads (Chapter 5) and a set of recommendations specific to wildlife crossing structures on the OT-GS Road (Chapter 6). More detail on specific recommendations can be found in Chapters 5 and 6. A brief summary of the recommendations made by the research team is provided below.

Oyu Tolgoi, LLC should be recognized for their commitment to a net positive impact on biodiversity. Efforts made by OT in this region could have a lasting impact on protection of endangered species. Further, the efforts by OT could set the standard for wildlife mitigation for future infrastructure projects in the region.

The 12 m wide wildlife underpasses that were previously proposed, particularly with no features to guide animals to the structure, are likely to fail in mitigating the fragmentation effect of the OT-GS Road for the target species. We suggest that wildlife crossing structures are constructed based on a phased approach.

- Phase 1A includes immediate design and construction of several wildlife crossing structures in the central valley area. This Phase could include six wildlife crossing structures of varying size and type at three sites. The proposed study design includes three locations (crossing locations 7, 8 and 9, Figure 35), each location with up to two crossing structures. Each location will have either an overpass or a paired underpass and overpass of similar width. This comparative approach to the initial phase of construction will provide evidence-based data for the planning and designing for later phases. Construction of phase 1A should preferably be implemented as soon as possible.
- Phase 1B includes the design and construction of two wildlife crossing structures, and adding features (e.g., fencing and visual barriers) to a 10 m bridge currently under construction. These three structures are in the granite outcrop area. This phase could be implemented soon, but only if it does not impede the progress of phase 1A.
- Phase 2 includes the design and construction of additional wildlife crossing structures in the granitic outcrops close to the OT mine and in the central valley. This phase should be informed through the monitoring of phase 1A and 1B.
- Phase 3 includes wildlife crossing structures in the Small Gobi B strictly protected area. This phase should only be implemented as part of a comprehensive wildlife mitigation plan for all transportation infrastructure in this area.

In addition to the phased implementation of wildlife crossing structures, we recommend that OT:

- Develops a monitoring plan for phase 1A structures (and also for phase 1B),
- Continues to support baseline fauna surveys,
- Continue OT roadkill recordkeeping,
- Develops and anti-poaching program that includes regulations, enforcement and public education,
- Develops a public education program for wildlife issues,
- Installs and maintains warning signs on livestock crossings
- Continues OT vehicle speed monitoring

We do not recommend implementing barriers, intended to keep vehicles from leaving the road, at least not for the entire length of any of the OT roads. These barriers should be considered in conjunction with wildlife barriers and visual barriers near wildlife crossing structures.

Refer to Chapter 6 for detailed design recommendations for the wildlife crossing structures and associated features. The most important recommendations are summarized here:

- We currently have insufficient data to evaluate the currently proposed 16 structures with a 6 km spacing distance. However, we recommend that the number of crossing structures and spacing is revisited if more data are available (e.g. wildlife movement data, population viability modeling, data on the use of different types and dimensions of crossing structures).
- Wildlife crossing structures, whether overpass or underpass, should be open with very gradual approaches and a clear line of sight for at least several hundreds of meters across the crossing structure.
- Visual barriers to hide traffic from animals should extend for 500 m either side of the structure. Wildlife barriers and barriers to keep vehicles from driving off-road should be implemented in the immediate vicinity of the structures. These three items (visual barriers, wildlife barriers and driver barriers) could be combined into one element.

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