APPENDIX

8-2 *WILDLIFE MITIGATION PLAN*

WSP CANADA

FEBRUARY 2022

WILDLIFE MITIGATION PLAN FOR THE RIRONI-NAKURU-MAU SUMMIT HIGHWAY UPGRADE, KENYA

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WILDLIFE MITIGATION PLAN FOR THE RIRONI-NAKURU-MAU SUMMIT HIGHWAY UPGRADE, KENYA

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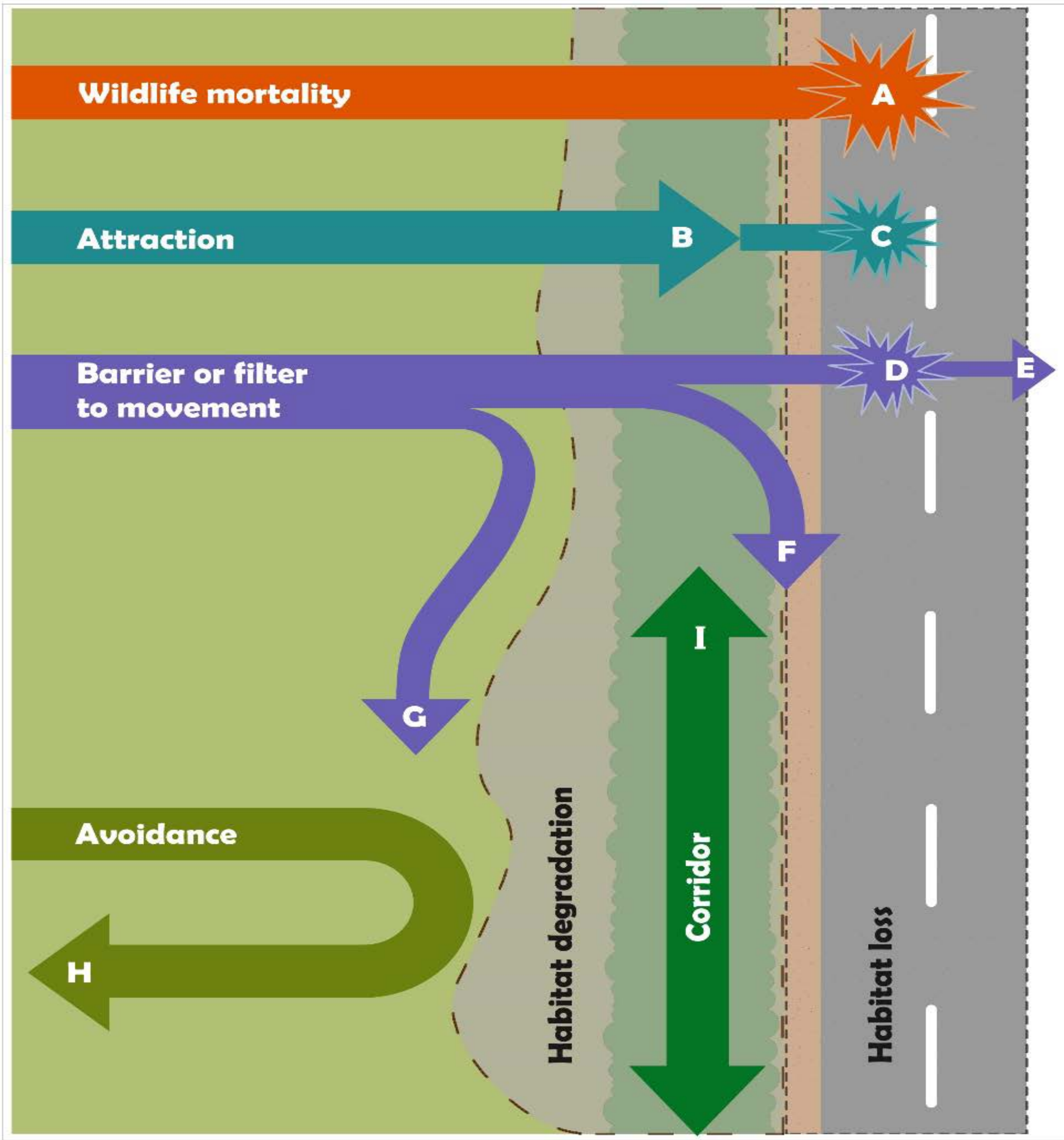
1 INTRODUCTION

Roads and other linear infrastructure are conspicuous and pervasive components of many landscapes around the world and exert a diverse suite of typically negative direct and indirect impacts on wildlife, vegetation and ecosystems (Figure 1.1). Individually and combined, these impacts reduce the diversity and abundance of wildlife in the area, thereby reducing the size of each discrete sub-population and the size of the overall population in the area. Ultimately, these impacts can result in the local and regional extinction of populations of wildlife.

The impacts of roads and traffic on wildlife include (van der Ree *et al.* 2015c); Figure 1.1):

- barrier or filter to the movement of wildlife, reducing accessibility of food and shelter on a daily basis, and preventing or limiting dispersal and annual migrations of wildlife over longer time-frames
- injury and mortality of wildlife due to wildlife-vehicle collision (WVC)
- loss of habitat due to clearing for road construction and maintenance, and subsequent loss of habitat clearing beyond the footprint of the road due to facilitated access
- habitat fragmentation as patches of habitat are divided into smaller patches
- degradation of habitat due to noise, light and chemical pollution, weed invasion, altered hydrological regimes, etc.

The severity of these impacts varies according to road conditions (i.e. traffic volume, road width, traffic speed) and landscape and environmental characteristics (i.e. habitat type, extent of clearing, etc.). The characteristics of the wildlife species that are resident or moving through the area is also an important factor, such as the frequency with which they encounter and attempt to cross roads, the speed with which they attempt to cross the road, and their response to oncoming traffic, such as to flee or freeze. These impacts, when considered singly or in combination, typically result in negative effects on wildlife, ultimately reducing population sizes and increasing the risk of local extinction, particularly for species that are rare or have small populations.



(Source: Zoe Metherell in van der Ree et al. 2015c)

Figure 1.1 Impacts of roads on individual wildlife, populations and ecosystems. Habitat is lost to build the road and habitat adjacent to the road is degraded. The most obvious impact of roads and traffic on wildlife is mortality due to wildlife vehicle collisions (WVC) (A). Some species are attracted to resources (e.g. carrion, spilled grain or heat for basking) on the road or roadside (B) which, depending on the animals ability to avoid traffic, may result in death due to WVC (C). The barrier or filter effect reduces the movement of animals across the road and a proportion of individuals attempt to cross are killed due to WVC (D) and some make it across (E), while others are deterred from crossing by the road (F) or degraded roadside habitat (G). Other species actively avoid the road or degraded habitat (H). In contrast, some species use the roadside vegetation as habitat and/or corridor for movement (I)

2 POTENTIAL IMPACTS OF THE RIRONI-NAKURU-MAU SUMMIT HIGHWAY UPGRADE ON WILDLIFE

Some of the potential impacts of the proposed upgrade of the Rironi-Nakuru-Mau Summit Highway (hereafter the 'project') on wildlife are likely to be significant and are summarised in Table 2.1 and described in more detail in Sections 2.1 to 2.6.

Table 2-1 Summary of the ecological effects and consequences of roads on wildlife

POTENTIAL EFFECT	EXAMPLE	CONSEQUENCE FOR WILDLIFE
Injury and mortality of wildlife due to collision with vehicles	Collision with moving vehicle	Injury and mortality results in smaller populations, and animal welfare implications Smaller populations are at an increased risk of extinction Less genetic variability can lead to inbreeding depression and loss of evolutionary potential Pain and suffering due to injury and potentially slow death
Direct and indirect loss and degradation of habitat	Reduced amount of habitat in area for wildlife to occupy Habitat may be degraded due to weeds, noise, light, chemical pollution etc, reducing the carrying capacity for wildlife	Lower rates of reproduction and survival due to increased rates and/or severity of disease and pathogens, increased stress Reduced ability to hear predators, prey or mates or find food due to noise pollution Reduced population size, contributing in longer-term to increased risk of local extinction
Reduced ecological connectivity	The road passes through habitat, dividing it into two, with reduced or no movement of wildlife between habitats The road passes through a wildlife corridor or other area that provides connectivity, reducing movement of wildlife between areas of habitat	Wildlife unable to access food, shelter, mates or avoid predators, resulting in reduced survival and reduced reproductive output Reduced gene flow among populations, resulting in inbreeding depression and less genetic variability to adapt to future environmental conditions Small or declining populations are unable to be bolstered by incoming individuals

2.1 WILDLIFE-VEHICLE COLLISIONS AND WILDLIFE MORTALITY

All roads with traffic have the potential to result in the mortality of native animals from wildlife-vehicle collisions (WVC). The risk of roadkill is higher where:

- Roads traverse through or between areas of wildlife habitat, including wildlife corridors
- Roads are located in close proximity to natural or artificial water bodies

- There are food sources (e.g. mown grass verges, nectar-producing shrubs or roadkill carcasses for scavenging species) which attract animals to the road or road edge
- Roads have moderate to high traffic volumes and high vehicle speeds
- There is no fencing or other barriers to prevent or limit movement of wildlife onto the road and road verge
- There is low visibility for both motorists and/or wildlife to detect and avoid each other (e.g. due to bends, crests or poor lighting).

Many species are vulnerable to injury and mortality (or roadkill) from roads, with the impacts on populations differing among species (Donaldson and Bennett 2004). The rate of WVC varies according to the speed with which wildlife attempt to cross the road, their response to oncoming vehicles (i.e. flight or freeze), their ability to move out of the way of oncoming vehicles and the frequency and duration of time the species encounters or is attracted to the road.

The severity of the population-level impact of wildlife mortality depends on the size of the population (smaller populations are at greater risk of local extinction), the natural rates of reproduction, mortality and longevity, and the degree of connectivity to other populations that may 'rescue' the declining population.

Numerous studies have quantified the rates of roadkill of different species across Africa, including in Mikumi National Park Tanzania (Drews 1995), Tsavo National Park Kenya (Lala *et al.* 2021), the Greater Mapungubwe Transfrontier Conservation Area (Collinson *et al.* 2019b) and the Tarangire—Manyara ecosystem of Tanzania (Kioko *et al.* 2015). These studies demonstrate that a large and diverse range of species are subject to roadkill, including on sealed and unsealed roads, on high and low traffic-volume roads and roads within and outside conservation areas. However, higher rates of collision are often observed where roads with high traffic volumes and high traffic speed pass through areas with high quality habitat and diverse and abundant populations of wildlife.

The impacts of roads and traffic varies among species according to their behaviour and life history traits (Fahrig and Rytwinski 2009). For example, raptor species and other scavengers are often attracted to the carrion left on roadsides, although if sufficiently mobile and able to avoid vehicles, these species may experience a net benefit from increased food availability. Amphibians and reptiles may be attracted to warm or wet roads and problems arise when they must cross the road in their annual migration to access different habitats on opposite sides of the road. This group show the greatest negative effect from roads due to their relative lack of mobility and low car avoidance behaviour. Small mammals generally show a positive or no effect, with impacts increasing with size in mammals and size of movement range, and depending on whether their predators have been affected.

The baseline studies completed for the ESIA demonstrate a diverse suite of mammals, birds, reptiles and amphibians in the study area with a large proportion of species being recorded in the various National Parks and private conservancies in the area. There was no existing comprehensive data on the rate of WVC along the highway, however the National Museum of Kenya (Appendix 1) has provided some anecdotal evidence and opinion on species at risk from WVC. This list of species is illustrative only, and the studies across Africa (e.g. (Collinson *et al.* 2015; Drews 1995; Kioko *et al.* 2015; Lala *et al.* 2021) demonstrate that the rate of WVC can be high on some roads.

Surveys of roadkill animals were undertaken during fieldwork for the two baseline surveys by scanning the roadsides while driving around the study area. The surveys were intense, with 11 staff across six vehicles from 16 to 26 February 2021 and 12 staff across seven vehicles from 13 to 25 April 2021. The entire project alignment was traversed, and many sections were traversed multiple times during each survey period, with all travel conducted between 07:00 hrs and 17:00 hrs. The total amount of time spent travelling during these two trips was 132 expert-days in February and 156 expert-days in April and included the A8, A8 South and other roads and areas in the study area. A total of four carcasses were detected during these two survey periods, namely an Egyptian Mongoose, a Baboon, an unidentified owl and a Zebra along the A8 adjacent to Marula Estate.

Repeated systematic surveys across multiple seasons were not conducted because anecdotal evidence and the results of the intense field survey confirmed that the rates of wildlife roadkill were very low. In addition, systematic surveys along the entire project were not feasible because: (i) the long length of the project; (ii) the safety risk posed to project staff to inspect dead animals found on the road; (iii) the likely rapid removal of larger roadkill by local communities for their meat; and (iv) the fast rate with which smaller-bodied animals would be scavenged or be destroyed beyond recognition.

In addition, KWSTI, Soysambu and Marula Estate have installed wildlife fencing along much of the A8 which is installed and maintained to reduce the rate of WVC in those areas. Importantly, the occurrence of fencing in these areas means that roadkill animals only show where the animal was killed, and not necessarily where it entered the highway verge. Therefore, in these three areas of the project with the highest diversity and density of wildlife, roadkill data would not be spatially accurate enough to inform the specific placement of the wildlife crossing structures (WCS). Instead, the project has relied on habitat suitability modelling and wildlife surveys to determine the optimal placement of fencing and WCS.

Nevertheless, the duplication and safety improvements in the design of the highway will likely result in an increase in both the speed and the volume of vehicles and thus the rate of WVC is expected to increase after the project is finished, along with a concomitant increase in the likelihood of injury and fatality of motorists from WVC.

2.2 HABITAT LOSS

The loss, fragmentation and degradation of habitat are some of the most significant causes of the decline in biodiversity globally. The consequence of habitat loss for wildlife is a reduction in amount of habitat to support wildlife, which results in smaller populations and an elevated risk of population extinction.

The amount of habitat being cleared for this project is relatively small because the vast majority of the project can be accommodated within the existing road reserve. Some vegetation removal within the road reserve is required, however much of this is low-quality regrowth. Some additional clearing outside the road reserve is required for bridges, large interchanges and quarries for construction materials. Nevertheless, even roadside vegetation can provide habitat for some generalist species of wildlife, and the widening and duplication will have some impact on relatively common and widespread species that use or are able to persist in the roadside vegetation.

2.3 HABITAT FRAGMENTATION AND REDUCED CONNECTIVITY

The movement of animals, plants and ecosystem processes is critical to species survival and healthy ecosystems. Clearing and construction of roads commonly result in habitat fragmentation, thereby limiting or preventing animal movements, creating smaller populations that are more susceptible to decline. Roads and traffic can form a barrier or filter to movement for certain species, particularly those that are sensitive to the noise, light and disturbance caused by vehicles. The existing highway is likely to act as a barrier or filter to the movement of many species, and the severity is likely to increase significantly due to:

- An increase in the number and speed of vehicles, including trucks
- An increase in the width of the gap between habitat on opposite sides of the road
- An increase in the levels of noise, light and chemical pollution
- The inclusion of concrete Jersey barriers between the two carriageways, which prevents many small and medium-sized animals from traversing
- Proposed fencing in some sections of the project

This increase in the barrier effect of the highway will have significant impacts for many species, and is likely to increase the risk of extinction of some species.

2.4 HABITAT DEGRADATION FROM LIGHT, NOISE AND CHEMICAL POLLUTION

2.4.1 ARTIFICIAL LIGHT AT NIGHT

Artificial light that alters the natural patterns of light and dark in ecosystems is referred to as 'ecological light pollution' (Longcore and Rich 2004). Types of ecological light pollution include chronic or periodically increased illumination, unexpected changes in illumination, and direct glare (Longcore and Rich 2004). Light pollution from the project has the potential to impact fauna during construction through use of artificial lighting for early morning or night work (if required), as well as ongoing (during the operational phase of the road) from car headlights and street lighting. Street lighting will likely be kept to a minimum, with lights at some interchanges, in urban areas and not along the entire highway itself. With regard to construction lighting, night work is unlikely to be required and would be short-term only.

Artificial light affects species in different ways but the main responses are:

- Disorientation – Artificial light sources may disorient night flying species including birds and bats, as well as other species such as turtles (Gleeson and Gleeson 2012). Conversely, artificial lighting may increase orientation, providing a benefit to particular species.
- Attraction – Some predator species are attracted to the lights due to the increased insect activity (Patriarca 2010), as are some species of insectivorous bats. Wading birds have also shown increased foraging success under artificial lighting (Santos *et al.* 2010), however, this may lead to increased predation.
- Avoidance – Some species may avoid well-lit areas due to an increased risk of predation (Longcore and Rich 2004), however, it can be difficult to separate any avoidance behaviour shown by fauna as being the result of the lighting compared to noise or a physical barrier (Gleeson and Gleeson 2012).

The above responses may affect foraging, reproduction, communication, and other critical behaviours (Longcore and Rich 2004). One of the most notable implications of light pollution is alteration of interspecific interactions (e.g. predator-prey and competitive interactions) (Longcore and Rich 2004).

The impacts of the proposed highway upgrade from lighting are expected to be minimal because street lighting is not planned in areas where the highway passes through important wildlife habitat.

2.4.2 NOISE

A recent study has demonstrated that there is unequivocal evidence that noise is one of the factors responsible for the road-effect zone on birds (McClure *et al.* 2013b). The noise from road construction and operation can be stressful, eliciting a physiological stress response, with some animals temporarily or permanently moving away from the noise. Species that remain exposed to the noise have experienced a range of responses, including reduced breeding success (Halfwerk *et al.* 2011; Reijnen and Foppen 1994) and lower survival rates, potentially such that otherwise suitable habitat is no longer occupied (Slabbekoorn and Ripmeester 2008).

There is also an increasing body of evidence demonstrating a variety of responses to anthropogenic noise in frogs, birds and other species that rely on acoustic signals (Brumm 2004; Hoskin and Goosem 2010; Parris and Schneider 2008; Slabbekoorn and Ripmeester 2008). One of these impacts is masking, or where the noise interferes with the acoustic signals critical to many animal species (Halfwerk *et al.* 2011), including calling to attract mates, territory defence, and warning of predators. The negative effect of traffic noise on birds depends on the temporal and frequency (Hz) overlap with relevant acoustic sounds, such as their own song or calls of predators (Brumm and Slabbekoorn 2005). Most birds call to defend territory and attract mates, with much of this occurring around dawn. The impacts of traffic noise on birds can be particularly acute if this dawn 'chorus' of their calling coincides with morning peaks in traffic.

Similarly, some species of bats that rely on acoustic signals to locate their insect prey are disadvantaged close to noisy roads (Schaub *et al.* 2008; Siemers and Schaub 2011). A recent synthesis of the effects of traffic noise on birds suggested that masking typically occurs with noise levels between 50 and 60 dB (Dooling and Popper 2007).

There are two main components to noise which is relevant here: frequency, or pitch, which is measured in hertz (Hz); and, amplitude (also referred to as loudness), which is measured in pressure or intensity, and is expressed in decibels (dB). The decibel (dB) is a logarithmic scale that allows a wide range of values to be compressed into a more comprehensible range, typically 0 dB to 120 dB.

CONSTRUCTION VIBRATION AND NOISE

Vibration is predominantly expected to be short term during the construction phase which involves piling works and vibratory compaction of ground surfaces. Vibration is generally considered unlikely to impact fauna, as it will be short term and has only local impacts (i.e. near the site of the machinery). However, even short-term impacts during the breeding season for threatened fauna should be avoided, where possible.

A small number of studies have shown that exposure to high-intensity construction and traffic noise can result in temporary or permanent hearing loss in animals (Brattstrom and Bondello 1983; Dooling and Popper 2007). The sound pressure level of continuous noise that induces temporary hearing loss in birds is 93–110 dB(A) and higher levels are required to potentially cause permanent loss, while levels of pulses need to exceed 125 dB(A) to permanently damage hearing in birds (Dooling and Popper 2007).

OPERATIONAL NOISE

Substantial variation has been shown in scientific studies in the responses of wildlife to human-generated noise and vibration, ranging from serious to non-existent in different species and situations. The main impacts on wildlife associated with noise are behavioural. Vehicle noise has been shown, particularly in some species of birds and frogs, to interfere with communication essential for reproduction. An increase in traffic noise may impact birds' ability to maintain territories, attract mates and maintain pair bonds and possibly lead to a decrease in mating success (Parris and Schneider 2008). Noise may affect behaviour by causing animals to retreat from favourable habitat near noise sources, reducing time spent feeding and resulting in energy depletion and lower likelihood of survival and reproduction (Larkin 1996). These impacts will be most pronounced in species with low-frequency signals as they are likely to experience the most interference with traffic noise.

There is little information available regarding the significant species in the study area. In a study in Finland, highway construction at a wetland resulted in the abundance in wader birds breeding nearby (up to 200 m) dropping by 80%, with decline linked to road noise above 56 db (Hirvonen 2001b).

There have been several attempts to identify a threshold level in traffic noise above which negative impacts occur. Dooling & Popper (2007) suggested limits of 93–110 dB(A) for continuous traffic noise to prevent temporary hearing loss in birds, and pulses to not exceed 125 dB(A) to prevent permanent damage to hearing. Dooling and Popper (2007) also tentatively suggested that noise levels from roads should not exceed 50–60 dB(A) to prevent masking and other similar effects while a more recent study suggested the threshold was 49 dB(A) (Wiacek *et al.* 2015).

McClure et al (2013a) and Ware et al. (2015) both found a significant effect to propagated road noise at 55 dB(A)Leq within a road-free landscape with a background noise level of 41 dB(A), demonstrating a maximum threshold (i.e. 55 dB(A)) that should be avoided. Unfortunately, no studies have evaluated a range of noise levels to identify where thresholds might occur, and thus the 55 dBA Leq should be considered a maximum threshold. Much lower thresholds in acceptable noise levels for all species of breeding birds in woodland (42–52 dB(A)) and open grassland (47 dB(A)) in the Netherlands were suggested by Reijnen et al. (1997). Numerous studies that compared noisy environments with quieter ones had quiet environments around the 31 L10 18 h dB(A) SPL (Parris and Schneider 2009), and 42 dB(A) (Wiacek and Polak 2015) levels. A study of wetland birds in Finland found a negative effect where noise levels exceeded 56 dB, implying that this SPL may represent a threshold in that study (Hirvonen 2001a). An updated review by Dooling and Popper (Dooling 2016) found that masking can occur above ambient noise levels but that, given behavioural adaptation strategies, noise guidelines in the range of 50–60 dBA would be appropriate.

From this body of evidence, and relying largely on the comprehensive reviews by Dooling and Popper (2007 and 2016), where specific information is not available regarding the sensitivities of the species of interest, traffic noise should be kept below 60 dBA. This is likely to be especially important during the morning chorus and during breeding.

The noise impacts of the existing highway are likely high because of the frequent need for vehicles to slow down and rapidly accelerate to overtake slow vehicles, especially in the hilly areas to the north and south of the project. The need for repeated breaking and accelerating will be reduced after duplication. However, the increase in traffic volume and speed overall will likely result in an increase in vehicle noise.

2.4.3 VISUAL IMPACTS

Closely linked to the impacts of artificial light is the visual impact of the road, a large artificial structure with moving vehicles, raised in key points above the surrounding landscape and the impact this has on fauna behaviour.

The impacts of the presence of artificial structures and car movement (as separate from noise, light and mortality impacts) are poorly known, however, it is understood that certain species, including Giraffe, may be affected. This may lead to decreased use of habitat nearby to the highway.

The increased effect of the duplicated highway is unlikely to be significantly more than the existing highway because the upgraded road is in the alignment and with only minor modifications to the vertical height of the road to accommodate additional underpasses in select locations.

2.5 CONSTRUCTION IMPACTS

Mortality of wildlife during construction may occur during clearing, or during instances when wildlife strays into the construction zone (van der Ree *et al.* 2015d). The potential for injury and mortality of wildlife from the project is expected to be low because almost all clearing is expected to be within the already highly-disturbed existing road easement. Nevertheless, the injury and mortality of wildlife during construction is feasible and is summarised in Table 2.2

Table 2-2 Summary of potential for increased injury and mortality from construction phase

ACTIVITY WITH POTENTIAL TO CAUSE MORTALITY	WILDLIFE WITH POTENTIAL TO BE AFFECTED	NATURE AND MAGNITUDE OF THE IMPACT
Vegetation/habitat removal during construction: Removal of mature trees with hollows and dead standing trees	— Hollow-dependent bats — Hollow-nesting and canopy-nesting birds — Arboreal mammals — Arboreal reptiles — Arboreal frogs — Invertebrates	Some potentially hollow bearing large old trees are likely to be removed for the project. Conduct a pre-construction walkover tree survey within the road reserve to identify any active nests of hollow-nesting and canopy-nesting birds. If a threatened bird species is nesting, consult a local avifauna specialist for guidance on actions to be taken. The level of mortality and injury of both non-threatened and threatened species of birds, bats, arboreal mammals is likely to be lower with mitigation measures in place.
Removal of understorey, groundcover, topsoil and debris (wood, rocks, rubbish etc.)	— Small woodland birds — Ground-dwelling reptiles — Frogs — Invertebrates	Mortality of species of native (non-threatened) reptiles and frogs is likely to occur from vegetation clearing and soil excavation works

Machinery/plant and vehicle collisions with fauna during construction	— Terrestrial, semi-aquatic and arboreal reptiles, frogs and mammals — Birds	Occasional mortality of native animals may occur during vehicle movements within the study area. This is unlikely to be a substantial risk as construction speed limits would be low.
Other causes of mortality (trenches etc)	— Terrestrial, semi-aquatic and arboreal reptiles, frogs and mammals	Without sufficient controls, mortality may result from fauna falling into trenches or sheltering in construction materials. This risk can be substantially reduced by minimising the duration that trenches remain open, ensuring trenches have frequent sections with shallow slopes that animals can climb and escape, pre-construction inspections are conducted at dawn to rescue any trapped animals, and fencing to prevent wildlife from falling in.

2.6 INDIRECT IMPACTS

Whilst the direct impacts of roads and traffic on wildlife are typically quite obvious (i.e. Sections 2.1 to 2.5), there are other more subtle factors that should be considered. Indirect or secondary impacts occur indirectly from the direct effects of a development and can be the result of a complex sequence of interrelationships. For instance, indirect impacts may include the loss of habitat through degradation from weed invasion or pollution.

2.6.1 SECONDARY MORTALITY OF WILDLIFE

Carcasses from WVC are known to attract scavengers, especially mammals and birds. These opportunistic feeders are then at risk of being struck as they feed on the carcass. Secondary mortality shall largely be avoided by maintaining existing fences or constructing new fences in high quality habitat to prevent WVC and mortality of wildlife in the first place, thereby almost eliminating the risk of secondary mortality. In addition, the species most likely to bypass the fencing and be killed are more likely to be birds and smaller species, and they are likely to be quickly flattened by passing vehicles and thus not be an attraction to scavengers.

2.6.2 LOSS OF HABITAT THROUGH INVASIVE ALIEN SPECIES

Roads can facilitate and exacerbate the dispersal of invasive alien species by allowing movement through the landscape in ways that may have not been previously possible. The duplicated highway is unlikely to cause a significant increase in the spread of weeds because it is following the same alignment and is remaining largely within the same easement.

Increased spread of invasive alien species during construction is likely a more significant impact and will be managed through the development and implementation of an environmental management plan that is applied to the construction phase of the project.

2.6.3 LOSS OF HABITAT THROUGH INFLUX OF PEOPLE

New roads, railways and other linear infrastructure into wilderness areas increases accessibility of the area to people and subsequent colonization, illegal logging, clearing and agriculture and further infrastructure development (Selva *et al.* 2015; Southworth *et al.* 2011). This project is an upgrade of an existing sealed road and is not a new road in an otherwise unroaded landscape. Therefore, the impacts of additional loss of habitat through the influx of people to the area is expected to be negligible.

2.6.4 INCREASED MORTALITY OF WILDLIFE DUE TO POACHING AND BUSHMEAT HUNTING

In addition to increasing the accessibility of landscapes for human settlements and other development, new roads and other linear infrastructure also provide better access to natural areas and facilitates poaching and bushmeat hunting (Laurance *et al.* 2008; Laurance *et al.* 2006). The access that the existing highway provides for poaching and hunting is already substantial, and the increased risk of additional hunting pressure is expected to be low. Nevertheless, various strategies will be employed to minimise the risk of poaching and hunting where the roads pass through areas supporting wildlife populations.

3 AVOIDING, MINIMISING AND MITIGATING THE IMPACTS OF THE HIGHWAY ON WILDLIFE

3.1 PROJECT GOALS

The following goals have informed the strategy to reduce the impacts of the project on wildlife:

- The project will strive to avoid, minimise and mitigate deleterious impacts to wildlife, ecosystems and ecosystem processes.
- The project will, where possible, allow the movement of wildlife for all types of movement, including foraging and other day to day activities, dispersal and annual migration.
- The project will aim to reduce rates of WVC along the length of the project and prevent WVC in areas of high-quality habitat for wildlife.

3.2 PLANNING AND DESIGNING FOR THE FUTURE

An important consideration in the planning and design of this highway has been the incorporation of the needs of wildlife that are either currently absent or in very low numbers but for whom there is a reasonable likelihood of occurrence or increased abundance into the future. For example, the study area is recognised as an important landscape for a wide diversity of species and efforts are underway to improve linkages and corridors at a regional scale, including habitat protection and restoration and the removal of unnecessary fences and other barriers. Therefore, while species occurrence has been a primary determinant of mitigation, this project is being future-proofed to provide some capacity for the introduction or natural colonization of additional species and increases in the abundance and distribution of existing species.

3.3 THE MITIGATION HIERARCHY AND CONTROLS FOR THIS PROJECT

Mitigation is the third step in the mitigation hierarchy and is considered after avoidance and minimisation, and before offsets and compensation. The mitigation hierarchy has been applied in the following order to achieve no net loss, or ideally, a net gain in biodiversity values:

- Avoidance – can the sensitive area be avoided completely resulting in no impact?
- Minimisation – If the sensitive area cannot be avoided, can the potential impact be reduced through design, such as a reduced clearing footprint or moving the section of highway to another location?
- Mitigation – For impacts that are unable to be avoided or minimised, can structural features be added to the highway to further reduce the impact? These can include under- or over-passes for wildlife, fencing to prevent wildlife accessing the highway, jump-outs to allow trapped wildlife to leave the fenced highway reservation, reduced vehicle speeds or wildlife detection and deterrent systems.
- Rehabilitation or restoration – Can the severity or extent of any remaining impacts be lessened through restoration or rehabilitation at the site of impact?

- Offsetting and/or compensation – Any residual impacts that remain after working through the previous steps can be offset - where habitat elsewhere is bought and/or managed to achieve conservation gains – or compensated where funds are provided to support activities that can indirectly benefit the impacted entities, such as for research.

Avoidance should always be considered prior to developing minimisation and mitigation strategies, and can occur across a range of scales, including re-routing the entire alignment to avoid significant areas of biodiversity values or micro-siting to avoid smaller but still significant values, such as large old trees or small wetlands.

Minimisation and mitigation aim to reduce the severity of three main impacts of roads and traffic, namely (1) mortality due to WVC, (2) barrier effects, and (3) noise, light and pollution effects. Minimisation focuses on modifications to the design to lessen the overall impact, such as reductions in the width of clearing, while mitigation measures are typically structural features that address specific impacts.

This project is avoiding and minimising impacts to wildlife by restricting most of the construction works to the reservation of the existing highway. The mitigation measures proposed in this strategy will improve connectivity for wildlife and reduce the rate of injury and mortality of both motorists and wildlife from WVC.

3.4 METHODOLOGY TO IDENTIFY THE NUMBER, TYPE AND LOCATION OF WILDLIFE CROSSING STRUCTURES AND FENCING

The planning and design of the crossing structures for this project is based on expert advice from the Kenyan Wildlife Service (KWS) from 2017 and 2019, expert advice from other ecologists, extensive consultation with local stakeholders, the results of targeted wildlife surveys and wildlife connectivity modelling, and a review of the road design and international best practice in road ecology. The details of each are described in Sections 3.4.1 to 3.4.7

3.4.1 PRELIMINARY CONCEPT DESIGNS BY KENYA WILDLIFE SERVICE AND REVIEW BY THE BIODIVERSITY CONSULTANCY

During the preliminary planning for the project the Kenyan Wildlife Service (KWS) and the Kenyan Highways Authority provided an indicative assessment of the number and type of WCS and fencing required for this project (KWS 2017). These included 11 underpasses, two overpasses and fencing. The design of the crossings was further specified in the Schedule 2 (Design Construction Standards) that were adopted for the project. The Biodiversity Consultancy reviewed the 2017 assessment and confirmed that the 11 wildlife crossing structures were necessary and appropriately sized (Bennun *et al.* 2018). The same report also recommended that the number, location and design of the crossing structures be reviewed after conducting the baseline surveys, as well as the installation of fencing to prevent wildlife from accessing the road and to funnel them towards the crossing structures. In 2019, KWS, KeNHA and RVH reviewed the information and conducted a site visit and revised their recommendations to include an additional two underpasses, bringing the total to two land bridges and 13 underpasses. The location of these 15 structures is shown in Figure 3.1 and described in Table 3.1.

Table 3-1. Details of the 13 underpass and two overpasses proposed by the Kenya Wildlife Service for the preliminary design of this highway. These preliminary recommendations were reviewed during the ESIA and the final list is provided in Table 4.1.

ID	CHAINAGE (KM)	TYPE OF WILDLIFE CROSSING	SIZE (NUMBER, WIDTH X HEIGHT M)	LOCATION	DESCRIPTION
WLC1	22+825	Underpass	1 of, 5.0 x 3.5	Kijabe	Maintain Existing Underpass
WLC2	25+325	Underpass	1 of, 5.0 x 3.5	Kijabe	Demolition & reconstruction
WLC3	53+375	Underpass	2 of, 7.0 x 3.5	Naivasha East	New Multipurpose Underpass for KWSTI
WLC4	69+235	Underpass	1 of, 5.0 x 3.5	Marula	Demolition and reconstruction Underpass for Wildlife and livestock
WLC 5	70+220	Overpass	1 x 30.0	Marula	New Overpass, 30 m width
WLC6	71+340	Underpass	1 of, 5.0 x 3.5	Marula	New Underpass
WLC7	73+705	Underpass	3 of 5.0 x 3.5	Kigio	Demolition & reconstruction Underpass
WLC8	76+640	Underpass	1 of 7.0 x 3.5	Gilgil River	New Underpass
WLC9	81+620	Underpass	1 of 7.0 x 3.5	Marula- Near Gilgil Junction	New Underpass
WLC10	92+040	Underpass	1 of, 5.0 x 3.5	Elmenteita-Kariandusi	Maintain Multi-use culvert for wildlife and livestock
WLC11	99+380	Overpass	1 x 30.0	Soysambu	New Overpass
WLC12	103+285	Underpass	1 of, 5.0 x 3.5	Maendeleo-Soysambu	Demolition & reconstruction of a new underpass
WLC13	104+665	Underpass	1 of, 5.0 x 3.5	Soysambu	Demolition and reconstruction of a new underpass
WLC14	106+215	Underpass	1 of, 5.0 x 3.5	Soysambu	Maintain existing underpass
WLC15	164+370	Underpass	1 of 7.0 x 4.5	Koibatek Forest - Near Itare Dam	New Underpass for wildlife and livestock

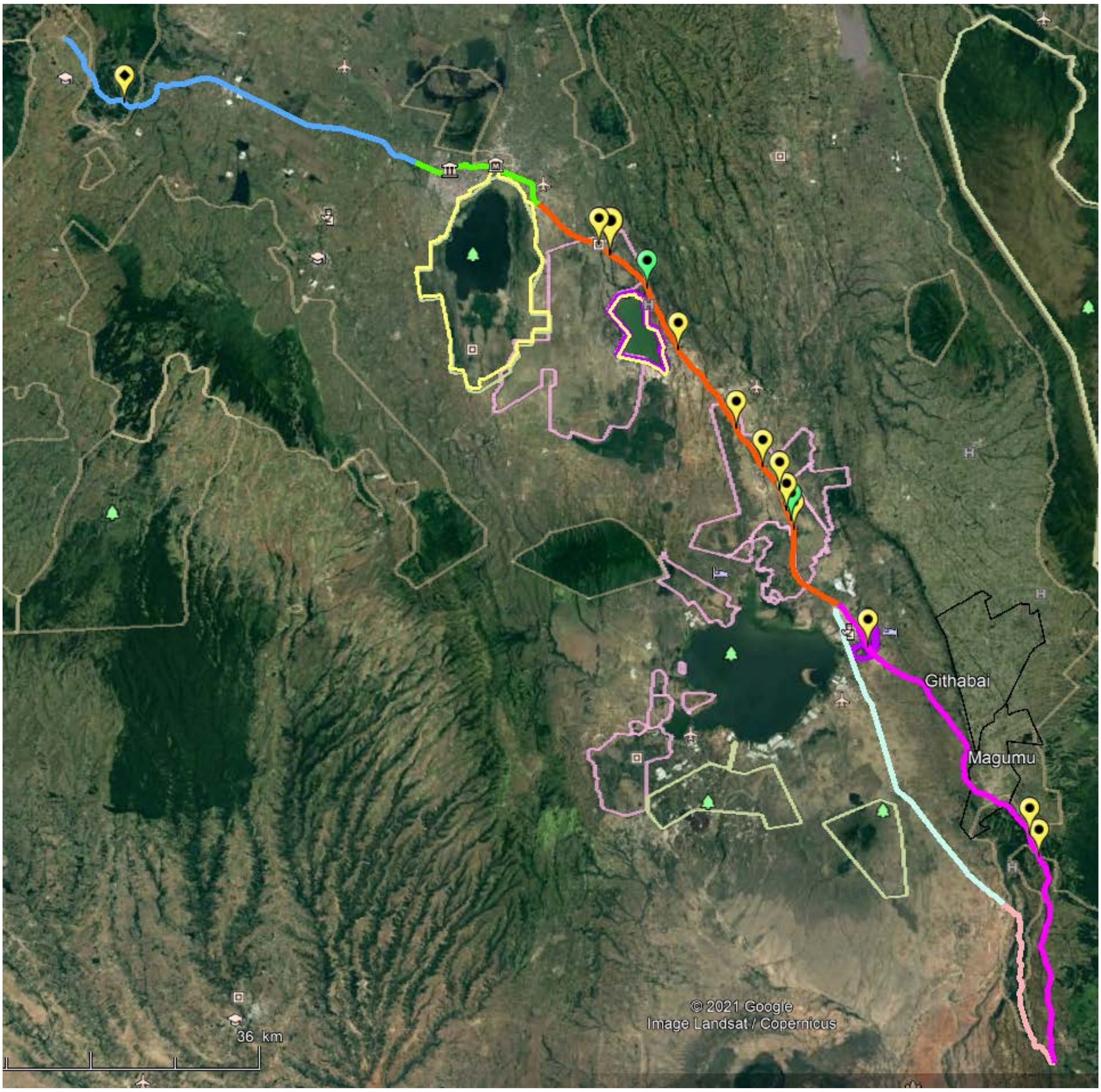


Figure 3.1. Map showing the location of the 15 wildlife crossing structures proposed by KWS, KenHA and RVC in 2019.

3.4.2 TARGET SPECIES

The Project passes through a diversity of ecosystems and numerous important habitat areas for wildlife, including Soysambu Conservancy, Marula Estate, the Kenya Wildlife Service Training Institute and the adjacent sanctuary, Lake Naivasha, Lake Nakuru and Mau Forest Escarpment. Two important areas with excellent data on species occurrence are Soysambu Conservancy and Marula Estate. Data provided by the managers of these two areas demonstrates the high species richness and in many cases abundance of wildlife that these conservation areas support (Table 3.2). It is also critical to note that these lists are not exhaustive because many smaller and cryptic species will not be detected during aerial surveys they used to survey their wildlife populations.

Table 3-2 Species list and number of individuals seen from aerial censuses undertaken at Marula Estate (2018) and Soysambu Conservancy (2020). Data courtesy of the managers of both areas.

SPECIES	SOYSAMBU CONSERVANCY (2020)	MARULA ESTATES (2018)
Aardvark	0	3
African Hare	10	0
Black-backed Jackal	0	100
Baboon	573	846
Bat-eared Fox	18	35
Buffalo	919	398
Bush Pig	3	8
Bushbaby	0	30
Bushbuck	0	9
C.Reedbuck	0	77
Caracal	0	1
Cheetah	0	1
Clawless Otter	0	1
Colobus Monkey	5	39
Hare	0	90
Crested Crane	0	67
Crocodiles	0	2
DikDik	36	99
Duiker	0	7
Egyptian Mongoose	0	5
Eland	252	458
Francolin	0	41
Genet Cat	0	14
Gerenuk	0	0
Giraffe	141	0
Gol Jackal	0	3
Grants Gazelle	256	97
Ground Hornbill	4	5
Guinea Fowl Flocks	95	49
Heartbeest (K.H) + (J.H)	0	7
Hippopotamus	0	108
Honey Badger	0	2
Hyena	22	0
Hyrax	19	105

SPECIES	SOYSAMBU CONSERVANCY (2020)	MARULA ESTATES (2018)
Impala	2528	3390
Jackal	29	0
Klipspringer	0	2
Leopard	1	5
Lesser Kudu	0	0
Lion	0	0
Mountain Reedbuck	0	3
Maasai Giraffe	0	41
Mongoose	4	0
Oribi	0	5
Oryx	0	8
Ostrich	0	12
Porcupine	0	7
Python	0	3
Reedbuck	0	0
S. Mongoose	0	4
Secretary Bird	8	5
Serval	1	2
Sid-St Jackal	0	2
Spotted Hyena	0	34
Springhare	0	76
Steinbuck	0	13
Stripped Hyena	0	1
Sykes	38	78
Thomsons Gazelle	716	1267
Topi	0	82
Tortoise	1	8
Vervet Monkey	123	112
White-tailed Mongoose	0	17
Warthog	57	291
Waterbuck	157	114
Wild Dog	0	0
Wildbeest	0	84
Zebra	4358	1801
Zorilla	0	3

3.4.3 TARGETED AND BASELINE WILDLIFE SURVEYS AND HABITAT CONNECTIVITY MODELLING

As part of the comprehensive studies for the ESIA, WSP commissioned targeted and baseline surveys of wildlife within the study area. This included the purchase and deployment of 50 cameras in Marula Estate and Soysambu Conservancy to quantify the distribution of wildlife in both conservation areas and to identify the optimal locations for crossing structures. These two conservancies were selected for the targeted surveys because:

- The A8 passed through both conservancies for relatively long distances
- They were identified as containing some of the largest areas of natural habitat and wildlife populations immediately adjacent to the project
- There were some anecdotal reports of WVC along the A8 in the vicinity of these conservancies
- They were relatively secure areas that would limit theft of camera equipment
- They had been identified as potential locations for WCS by KWS and others (Section 3.4.1).

WSP commissioned the University of Nottingham Malaysia (UoN) to analyse the results of the targeted camera trap surveys and the results are summarised in the ESIA and in the camera-trap report (Lechner *et al.* 2021a). The UoN was also commissioned to undertake a comprehensive wildlife connectivity modelling study to identify important habitat patches and linkages for wildlife in the area (Lechner *et al.* 2021b). The results of these analyses are presented in Appendix 6-19 and 6-20 of the ESIA, respectively.

The camera trap analysis focused on four key species because of their conservation status, proneness to collision with vehicles, risk of injury to motorists, knowledge of their ecology to inform the model and availability of occurrence data points. The four species were:

- African buffalo (*Syncerus caffer*) referred to as Buffalo
- Giraffe (*Giraffa spp.*). It is important to note that Soysambu Wildlife Conservancy has Nubian giraffe only (*Giraffa c. camelopardalis*), whereas Marula Estate has Masai giraffe (*Giraffa tippelskirchi*). However, the analysis conducted for this study uses the term Giraffe to refer to both species.
- Plains zebra (*Equus quagga*) referred to as Zebra
- Spotted hyena (*Crocuta crocuta*) referred to as Hyena

Nubian giraffes and Masai giraffes are critically endangered and endangered, respectively, and will require tailored crossing structures to be able to safely cross the A8. While considered near threatened and more common than Giraffe, Zebra and Buffalo can both move in herds and thus a group of individuals must be able to use a crossing structure at the same time. In addition, as large-bodied species, they also represent some of the greatest risks for motorist injury and fatalities as a result of WVC. Hyenas are predators and will thus have different requirements to the three species of herbivore. Finally, they also have the potential to act as 'umbrella' species and mitigation measures developed for these species will also be effective for many other species. However, a formal analysis of the degree to which these four species represent the needs of all other species has not been conducted and thus a conservative approach to the design and placement of wildlife crossing structures must be taken.

3.4.4 LITERATURE REVIEW AND BEST PRACTISE - WILDLIFE CROSSING STRUCTURES IN AFRICA

There is very limited published data on the use and effectiveness of wildlife crossing structures by African wildlife, with just three published studies identified in a recent comprehensive review (Collinson *et al.* 2019a), and an additional three studies published since then. The findings of each study and the implications for the design of WCS on this project are summarised in Table 3.3

Table 3-3 Summary of studies on the use of underpasses by wildlife in Africa

LOCATION AND TYPE OF STRUCTURES	FINDINGS	LESSONS FOR A8 AND A8 SOUTH	REFERENCE
Kenya – 1 x culvert 4.5m high, 6 m wide, 12 m long under the 2-lane A2 highway near Mt Kenya National Park. Fencing of corridor led elephants to the underpass.	Elephants used the underpass on the first night it was open, and >300 crossings recorded in the first year.	This study confirms African elephants will use underpasses when built at a known movement path, is fully fenced and when crossing a 2-lane road.	(Weeks 2015)
Kenya – Standard Gauge Railway (SGR) through Tsavo National Park, with 6 wildlife underpasses (70 m wide, 6 m high) and 9 large multi-use bridges that range in length from 20 m – 1980 m and 4 m – 12 m high. The SGR is fully fenced in Tsavo Conservation area to prevent wildlife-train collision, and the old railway and highway, plus powerlines and pipelines are parallel to SGR	Tracked movements of 10 elephants with GPS collars between March 2016 and March 2019. Eight elephants used the WCS and/or multi-use bridges under the SGR and the remaining two elephants remained on the same side of the infrastructure and did not cross the old highway nor the SGR. 78% of crossings were made at night, and elephant speed much higher while crossing, implying a behavioural response in risky landscape and under stress. Limited detail of rates of use or preferences for different structure types given – but elephants did use dedicated wildlife underpasses and some multi-use bridges.	This study focussed just on the movement of elephants, so mostly relevant to northern sections of the A8 project, but some trends applicable more broadly. Need to ensure that parallel linear infrastructure are also mitigated. Transient human settlements near underpasses likely restricted rate of crossing. Large underpasses appeared to be used by Elephants more than smaller underpasses, but difficult to interpret the data given.	(Okita-Ouma *et al.* 2021; Okita-Ouma *et al.* 2016)
Kenya – Standard Gauge Railway (SGR) project between Mombasa on the coast and Suswa in the Rift Valley. SGR included bridges, underpasses, culverts and flyovers in National Parks for wildlife movement and noise barrier in Nairobi NP.	Used qualitative data from interviews with 54 people from diverse organisations to identify impacts of SGR. Ecosystem fragmentation was the 2nd most dominant theme during interviews. Participants noted the 'likely ineffectiveness of mitigation measures' due to many underpasses along the SGR became occupied by people, and wildlife avoided them.	The subsequent management of underpasses and exclusion of people was not managed well, and wildlife (note elephants were the primary species discussed) avoided the WCS and increased human-wildlife conflict elsewhere. Unable to draw conclusions about the suitability of the design and spacing of WCS on SGR from this study.	(Nyumba *et al.* 2021)
Kenya – Standard Gauge Railway (SGR) project has 150 underpasses, of which 6 wildlife underpasses, 8 bridges and 27 culverts were open for use by wildlife and use was monitored between July 2017 and January 2021.	Preliminary analysis of use of underpasses based on visual inspections, looking for footprints, dung and physical sightings of wildlife. A total of 25 species were detected using underpasses, with livestock, Baboon, Elephant, Mongoose and Zebra most frequently detected, accounting for 70% of crossings. Other	A range of different species of wildlife will use dedicated and multi-use underpasses to cross under SGR. Average rate of detection in underpasses was highest for open span bridges over waterways, followed by	(Save the Elephants 2021)

LOCATION AND TYPE OF STRUCTURES	FINDINGS	LESSONS FOR A8 AND A8 SOUTH	REFERENCE
	species included Antelope, Buffalo, Camel, Dik Dik, Civet, Hyena, Impala. Wildlife used underpasses of varying width and height, but wider underpasses and taller underpasses appeared to be preferred by large species, and species that move in groups. Some of the variation in rate of use of different structures is likely related to location and proximity to suitable habitat, use by livestock, proximity to human settlement and distance from the nearby Mombasa-Nairobi Highway.	dedicated wildlife underpasses and lowest for culverts. Larger animals and those that travel in groups appear to prefer larger structures. Highest rates of use were generally observed in taller and wider underpasses. All underpass types contributed to connectivity and all should be designed / adapted for use by wildlife. Use of the underpasses by livestock and people, and proximity to human settlement. is likely to reduce rates of crossing by wildlife.	
Diani Beach on the south coast of Kenya. 28 rope-ladder canopy bridges installed over approx. 10 km of the 10m-wide Diani Beach Road. Two days were spent in 2013 observing animals use each bridge.	The vast majority of the 28 bridges were used – most frequently by Sykes', followed by Colobus and Vervet monkeys. Baboons were not observed using the bridges. Rate of use influenced by location – optimal location in good habitat or original movement pathways	The canopy bridges reduced WVC and monkey mortality. Accurate identification of monkey movement pathways and optimal monkey habitat on A8 and A8 South is essential	(Donaldson and Cunneyworth 2015)
Experimental trials at Lajuma Research Centre in Northern South Africa. Roadkill data collected on provincial paved road varying between 2 and 3 lanes wide (6 and 9m). Experimental testing of two canopy bridge designs – being a rope ladder and a rigid bamboo pole - at 25 sites using a paired choice design.	Used direct observations of Samango Monkeys crossing roads at the canopy bridge locations and assessed if they used the tree canopy, canopy bridge (and type of canopy bridge) or by ground. Canopy bridges reduced the likelihood of crossing at ground; canopy bridges were preferred to trees and ground when the canopy was open; and pole bridges were preferred over rope ladders. A range of other species also used canopy bridges, including rodents, Thick-tailed and Lesser Bushbaby, and low rates of use by Chacma Baboon	Primates are impacted by linear infrastructure through mortality from WVC and gaps in canopy can reduce connectivity. Canopy bridges are preferred by Samango Monkeys to crossing at ground. Further research and testing of bridge designs for very wide roads required	(Linden *et al.* 2020)

LOCATION AND TYPE OF STRUCTURES	FINDINGS	LESSONS FOR A8 AND A8 SOUTH	REFERENCE
Trials of shade-cloth fences to prevent mortality of Western Leopard Toad during their annual migration in Noordhoek, Cape Town, South Africa.	The shadecloth fence resulted in a significant reduction (to zero in 2013) in the rate of mortality from WVC of the Leopard Toads, The WVC hotspots were very spatially restricted to certain locations and are typically not dispersed over large areas.	Fences can effectively reduce frog mortality and must be paired with WCS to enable movement between overwintering habitats and breeding habitats. Need excellent data on location of WVC hotspots and movement paths to identify where mitigation is required. Good data on design of amphibian tunnels available globally.	(Le Brun 2013)
Ongoing study of use of drainage underpasses (culverts and bridge underpasses ranging in size up to 15 m wide and 6 m high) under a railway in South Africa	Preliminary results show use by a wide range of species, including Warthog, Leopard, Lion and a range of ungulate species. While there are occasional records of wildlife using small culverts (e.g. 1 m x 1 m), the vast majority of species and the highest number of individuals are using larger underpasses (e.g. 15 m wide x 6 m high)	Data collection is still ongoing, but strong evidence that while wildlife will occasionally use quite small structures, the highest rates of use are through the largest underpasses.	Wendy Collinson, unpub. data
Underpasses under the existing A8	Limited anecdotal data on the use of the existing underpasses under the A8	Lack of any data on the use of the existing structures under the A8 strongly implies they are not being overwhelmingly used by wildlife. It is unclear if this apparent lack of use is due to fencing or other obstructions, co-use of the structures by stock and machinery, or sub-optimal size and/or location.	Unpublished anecdotal observations from locals

The evidence from the limited experimental trials and evaluation of implemented WCS in Africa, which is supported from research globally is that WCS and fencing allow the safe movement of wildlife across the infrastructure and reduce or eliminate rates of WVC and the mortality of wildlife (van der Ree *et al.* 2015a). However, there is also an increasing body of evidence that while crossing structures do facilitate the movement of wildlife, the crossing structures are often too small, too infrequent, or not placed optimally in the landscape to fully remove the barrier effect of the road or railway (Rytwinski *et al.* 2016). Therefore, in general, most roads and railways require more and larger crossing structures, positioned in the best locations in the landscape and managed better to ensure ongoing success.

Fortunately, many of the lessons learnt from road ecology internationally can be applied to this project. The underlying principles for the design of wildlife crossing structures for this project are as follows:

1. Due to the lack of local data on the use of wildlife crossing structures across 4-lane dual carriageway roads, a conservative approach to the minimum size of structures for this project has been adopted.
2. Fencing appropriate to the target species is required to prevent wildlife from accessing the road and funnelling them to structures, and these must be effectively designed and managed.
3. Different types and sizes of crossing structures are included to provide a diversity of crossing opportunities in the likely scenario that different species have different preferences.
4. Consider installing noise walls and light screens at crossing structures where sensitive wildlife occur, subject to feasibility assessment during detailed design, to minimise disturbance from passing traffic and enable sensitive wildlife to approach and utilise the crossing structures.
5. Where possible, large and dedicated crossing structures are located in conservation areas with (a) the greatest diversity and density of species to benefit from the investment; (b) long-term security of land for conservation and (iii) active management of land to achieve conservation outcomes.
6. Crossing structures will be installed in a range of habitat types and topographical positions (e.g. some along waterways, higher points in the landscape, etc).

3.4.5 EXPERT AND STAKEHOLDER INPUT

A range of experts and stakeholders were engaged intentionally and opportunistically over the course of the ESIA to obtain input into the planning and design of the mitigation measures. The expert and stakeholder engagement included:

- Two wildlife workshops to discuss the wildlife connectivity modelling, including with KWS and managers of Marula Estate and Soysambu (April 2021 and July 2021). Both these workshops were supported by a Web-based expert mapping and survey tool called Maptionnaire.
- Review of the camera-trap analysis and connectivity modelling by ecologists from the Endangered Wildlife Trust, Giraffe Conservation Foundation and Ewaso Lions and Grevy's Zebra Trust
- A workshop with researchers in Africa and South America to discuss the design and feasibility of canopy bridge crossing structures for arboreal animals.
- A third final wildlife workshop to present the results of the camera-trap study, wildlife connectivity modelling and the outcomes of the study in terms of Wildlife Crossing Structures (January 2021). The workshop aimed to get input and comments from stakeholders on the final selection and design of Wildlife Crossing Structures.

An overview of consideration of comments and recommendation received during the wildlife workshops is provided in the table below. Further details of the engagement process are provided in the wildlife connectivity modelling report (Lechner *et al.* 2021b and Appendix 6-20 of the ESIA) and also in the Stakeholder Engagement Chapter of the ESIA (Section 7.5.1). The minutes of the different workshops are available in Appendix 7-2 of the ESIA.

Table 3-4 Consideration of comments and recommendations received during wildlife workshops

WORK-SHOP	QUESTIONS, COMMENTS AND RECOMMENDATIONS	RESPONSE PROVIDED / CONSIDERATION IN THE ESIA / IDENTIFICATION OF MITIGATION MEASURES
1	How are domestic animals being considered for crossings ?	Cattle crossing location were discussed in detail during the consultations with local communities. The wildlife movement study aims to identify key crossing points for wildlife and proposes dedicated wildlife crossings as well as multi use structures. Dedicated wildlife crossings are more effective than multi-use underpasses because the use of crossing structures by people and livestock can disturb wildlife.
1 and 3	The consideration of primate species, especially in Soysambu and Marula especially at WLC 11	Primates are not specifically considered in the wildlife movement study, but they were covered by the biodiversity surveys. The crossing structures in Marula Estate, Soysambu and in the Forest Reserves will also accommodate smaller animals such as primates, and they are located in the best habitat and thus be most useful for primates. WLC 11 has not been selected as wildlife crossing structures in Soysambu have been limited to existing structures, as Soysambu management confirmed they would not like endangered wildlife they are protecting within their land on the western side of the road to cross over to the eastern side. Although part of Soysambu property, the eastern side of the road is characterized by a more important number of human settlements which represents a greater risk of poaching for the giraffes. Furthermore, they have sold part of their land on the eastern side for future development and are considering selling additional land in the same area.
1 and 3	The consideration of endemic small mammals, including the Naivasha African mole-rat (*Tachyoryctes naivashae*)	Small mammals are not specifically taken into account in the wildlife movement study, but they were covered by the biodiversity surveys. The crossing structures in Marula Estate, Soysambu and in the Forest Reserves will also accommodate small mammals and they are located in the best habitat and thus be most useful for small mammals. The only endemic small mammal which distribution overlapped with the RAA, is the Aberdare mole shrew (*Suridisorex norae*). This species is endemic to the east side of the Aberdare Mountain Range. The distribution of this species probably follows the top of this mountain range hence it is unlikely to be found in the LAA, close to the road and no impacts are foreseen. With regards to the African mole-rat, IUCN does not consider T. naivashae as an endemic species, and rather follows Happold (in press) by including *ankoliae, annectens, audax, daemon, ibeanus, naivashae, rex, ruandae, ruddi, spalacinus* and *storeyi* within *Tachyoryctes splendens*. This species is widely distributed in East Africa and eastern parts of Central Africa and is not considered endemic and/or restricted range. Thus this species is not considered endemic or restricted-range.
1	Consideration of wildlife movement between KWTI Campus game sanctuary and its annex sanctuary next to lake Naivasha, as well as the Game farm Sanctuary. Consideration of an overpass	Special considerations was given to the three sections of the KWSTI, i.e. main campus, game farm and annex. A 40 m wide landbridge is planned over A8South between the campus and the annex (WCS29), and a 20m x 7m underpass is planned under A8 between the campus and the game farm (WCS3), to accommodate large mammals, including giraffe.

	which would be more adequate for giraffe, at least 30 m wide.	
1	Connection between either side of the highway in the KWSTI should also be provided to visitors, that should be able to drive through either side. s	Connection will be ensured by the two WCS mentioned above WCS29 and WCS3). However, it is recommended these be wildlife dedicated to increase their use by wildlife, especially considering their potential use by sensitive species such as giraffe.
1	Crossings as large as possible so that fauna can easily find escape routes and avoid death traps, not only from predators but also poachers.	Previous experiences do tend to show that larger animals and those that travel in groups appear to prefer larger structures and that highest rates of use are generally observed in taller and wider underpasses. 5m is considered a reasonable width considering technical and economic considerations and should avoid death traps.
1	Proper lighting for underpass to be considered and proper drainage	Lighting of underpass not considered at it would discourage use by numerous wildlife species. Proper drainage will be integrated in the detailed design.
1	Consideration of the section of the road from Maai Mahiu, which involves many roadkill and high wildlife crossings.	No WCS are planned along A8South, except at the KWSTI. It is considered the road strengthening (no dualling) of A8South will not increase barrier effect nor roadkill and will increase security.
1	Consideration of possible elephant movement that come from the Aberdares into the Kereita Forest (WLC1 and 2)	The potential presence of elephant in this area was noted and considered. While the new crossing structures (5m x 3.5m) were designed to accommodate species that are known to regularly occur in this area (Kikuyu Escarpment Forest/Kinale Forest), including small ungulates and large carnivores, the existing structure (10 m x 5 m) will be maintained (WCS1) and will possibly accommodate elephant movement.
2	WLC2 seems too close to settlement to be effective.	The existing WLC at WLC2 will be maintained for multiple use by wildlife, people and livestock. A new dedicated underpass will be planned at a minimum of 250 m from the multi-use underpass away from settlement. Exact location to be determined in detailed design.
2 and 3	Concern about a 5 meter width under 4 lane traffic not offering enough openness	Previous experiences do tend to show that larger animals and those that travel in groups appear to prefer larger structures and that highest rates of use are generally observed in taller and wider underpasses. 5m is considered a reasonable width considering technical and economic consideration.
2	Need for jump out structures if any ungulates get stuck between the road and fence line	This recommendation was noted and integrated into the design. Jump outs and other escape opportunities will be provided within Marula and Soysambu to enable wildlife to escape from the highway wayleave and re-enter the two conservation areas, as fencing in these areas are planned in continuous length.
2	Need for noise pollution mitigation especially for giraffe.	This recommendation was noted and integrated into the design. Subject to feasibility to be determined during detailed design, the impacts of traffic noise will be mitigated primarily through the use of noise walls and/or soil berms at the dedicated wildlife crossings, and to a lesser extent through the use of vegetation plantings and light walls in lower priority areas. For the landbridge, it was recommended to install noise and light screening and vegetation on edge of bridge and on approaches to the bridge are required to stop noise and light from oncoming vehicles. Soil berms on the bridge are not recommended due to the additional weight and the extra space they occupy, compared to screens.

		For bridge underpasses, it was recommended to install noise and light screens on the edge the planned bridge to reduce disturbance to wildlife passing underneath. Noise and light screens should also be considered for 100 m either side of each underpass to reduce disturbance to approaching animals.
2	Plantation of tree species for giraffe on the overpass.	This recommendation was noted and integrated into the design. It was recommended for the landbridge to be vegetated with native shrubs and trees and include optimal habitat for giraffe in the middle of the overpass
2	WLC 7 – connects to an existing dirt road. Wildlife would not likely use this	WLC7 is an existing underpass, currently used by livestock, pedestrians and farming (also entrance to Kigio Estate). It is considered low feasibility for a dedicated WCS due to private land on both sides of road. The existing underpass is to be extended under new carriageway and a new multi-use underpass 7 m wide x 3.5 m tall is to be installed for wildlife, livestock, pedestrians and farm machinery.
2	Consideration of waterways as important corridors for wildlife including primates, amphibians, small mammals and predators. Including retrofitting provisions for wildlife at the Gilgil river bridge, the river to the north of marula conservancy, the Kinungi riparian zone and the Melewa River, considering year round water levels).	Existing river crossings were considered and provisions for wildlife were integrated into the design where feasible, including Melawa River Crossing (WCS19), Gilgil River Crossing (WCS8), River North of Marula Estate (WLC10), as well as at Kinungi River (WCS17) In general, it was included to add fencing, landscaping and revegetation to enhance use by wildlife.
2	The gap between WCL9 and WCL8 seems too long given there are a lot of ungulates along that stretch of road.	No additional WLC structures were identified in Marula Estate between WCS9 and WCS8 because important considerations in determining the location and design of crossing structures was given to the land tenure and management considerations. These considerations focus on the long-term security of land tenure for conservation and the ability to audit the use of such land for conservation purposes. Despite being important from a wildlife conservation perspective, Marula Estate are not protected in perpetuity, and the number and size of WCS in these areas reflects this significant constraint. All underpasses under the new carriageway at Marula Estate and Soysambu Conservancy will match or be slightly larger than what currently exists under the existing highway to act as multi-use underpasses.
2	Consideration of the conservancies' management plan to be assessed, so wildlife crossing are not use for moving cattle.	Important consideration in determining the location and design of crossing structures was given to the land tenure and management considerations. These considerations focus on the long-term security of land tenure for conservation and the ability to audit the use of such land for conservation purposes. Despite being important from a wildlife conservation perspective, Marula Estate are not protected in perpetuity, and the number and size of WCS in these areas reflects this significant constraint. All underpasses under the new carriageway at Marula Estate and Soysambu Conservancy will match or be slightly larger than what currently exists under the existing highway to act as multi-use underpasses.

2	WLC 12 – connects to a dirt road and would not be optimum for wildlife use. Idem WCS13 and WCS 14	WLC 12 was finally not selected because Soysambu sold the area east of the road for a residential development. Also, because of land tenure issues (Despite being important from a wildlife conservation perspective, Soysambu is not protected in perpetuity and long-term security of land tenure for conservation and the ability to audit the use of such land for conservation purposes cannot be assured) no new crossing structures were proposed in the area. It was recommended to maintain WCS13 and WCS14.
2	Manguo swamp is an important area for cattle crossing, which could also be used by small mammals.	No specific WCS is planned at Manguo swamp but there is an existing underpass that will be maintained as cattle crossing near Manguo Swamp, which could in fact be used my small mammals and other small wildlife.
2	Implementation of sound barrier along stretch near the Lake Elmentaita WHS	The implementation of a noise barrier near Lake Elmentaita was not considered feasible. However, it was included to ensure that the directives of the noise permit to be obtained from NEMA will also be applied in areas of high-quality habitat for wildlife, such as near Lake Elmentaita. Furthermore, noise modelling has not demonstrated significant increases of noise levels along the Project section located close to lake Elmenteita.
2	Consideration of putting a number of crossing structures along between the Longonot and Maai Mahiu area.	No WCS are planned along A8South, except at the KWSTI. It is considered the road strengthening (no dualling) of A8South will not increase barrier effect nor roadkill and will increase security. Vehicular traffic volumes on the A8South are also expected to decrease following the doubling of the A8, which should lower vehicle wildlife collision risks.
3	How has the location of quarries/borrow pits considered the presence of wildlife habitat ?	The location of source material and temporary construction sites are not determined yet. The information gathered in the ESIA will help guide decisions on the locations. A dedicated ESIA will be completed for each quarry site and will be submitted to NEMA to get approval
3	The consideration of smaller animals in the design of fencing.	The fencing design will be adapted to the target species. If in an area with important small mammals, or amphibians and reptiles populations, the bottom of the fence will be a smaller mesh, compared to the top of the fence.

3.4.6 REVIEW AND SYNTHESIS OF INPUTS

The final recommended mitigation measures in this ESIA were derived after reviewing the KWS recommendations, the results of field surveys and outputs of the connectivity modelling, and conducting a desktop assessment of the likely effectiveness and adequacy of the proposed recommendations against international best practice. This was combined with input and comments from the ecological experts and stakeholders.

3.4.7 PRIORITISATION OF CROSSING STRUCTURES AND LOCATIONS

Each location for a potential wildlife crossing structure was prioritised and categorized according to the following:

Ecological priority was determined by considering the diversity and abundance of wildlife in the area and the quality and tenure of habitat in the area

Expected use of a structure was classified as a priority for wildlife (i.e. high priority) or incidental (low priority)

Structure type describes the type and size of the structure – e.g. vegetated land bridge, bridge underpass, box culvert or canopy bridge

Structure focus describes whether the structure is being designed and constructed specifically for wildlife (i.e. dedicated wildlife crossing) or whether it is intended to function for other purposes in addition to the movement of wildlife, such as drainage or the movement of people and livestock.

Land tenure and management describes the current land-use and tenure of land adjacent to the proposed crossing structure, based on the following four criteria:

1. Adjacent landowners must commit to managing the land immediately surrounding each WCS and more broadly leading up to each WCS for the conservation of wildlife
2. All highway fencing at the WCS will be opened up to allow the free movement of wildlife through the WCS. Similarly, any gates at the WCS shall remain open at all times. Wildlife must learn that a location is an open crossing, and if it is periodically closed, they will not learn that it is an effective crossing
3. The primary use of dedicated WCS should be wildlife and the landowner must agree to this condition. Occasional use by vehicles, farm machinery and livestock can occur, but excessive use which results in the trampling of vegetation and ongoing disturbance to wildlife will reduce effectiveness for wildlife.
4. Adjacent landowners must agree to a long-term commitment with specific conditions that can be audited and compliance assessed by the relevant authority.

4 PROPOSED MITIGATION MEASURES

4.1 BACKGROUND

A wide range of novel and innovative strategies are being developed and employed locally and globally to minimise and mitigate the negative ecological impacts of roads and traffic. Many new roads are being planned and designed to reduce impacts on wildlife, following the mitigation hierarchy, focusing on avoidance as the first priority, followed by minimisation, mitigation and offsetting. The minimisation and mitigation strategies for road planning and design are numerous and include:

- wildlife crossing structures (WCS) (e.g. culvert and bridge underpasses, land bridges, canopy rope bridges and glider poles) to facilitate the safe movement of wildlife under or over roads
- fencing to prevent wildlife from accessing the road and funnelling them towards crossing structures
- noise and light walls to reduce the egress of visual and acoustic stimuli from the road into adjacent habitat
- temporary and permanent road closures, speed reductions and other traffic calming measures through sensitive habitats or at times of high-collision risk with wildlife.

The rates of use of wildlife crossing structures and the effectiveness of different approaches varies significantly depending on the type of treatment and the quality of the installation. For example, wildlife crossing structures and continuous fencing installed together and continuous fencing alone can reduce the rates of WVC by up to 90%. In contrast, there is still much uncertainty about the effectiveness of flight diverters (walls or other structures intended to encourage birds to fly up and over traffic) and ongoing trials and debate over the use of acoustic, chemical or light stimuli to deter animals from entering the roadway.

The mitigation measures for this project are:

- Wildlife crossing structures - underpasses and overpasses
- Fencing to prevent wildlife from accessing the highway and funnelling them towards crossing structures
- Noise and light screening in sensitive areas
- Fauna-sensitive lighting
- Management, maintenance, monitoring and evaluation

4.2 WILDLIFE CROSSING STRUCTURES

4.2.1 BACKGROUND

Wildlife crossing structures, including over- and under-passes enable the movement of wildlife over or under the highway and remove, or significantly reduce, the risk of collision with vehicles. Crossing structures have been installed around the world for a wide diversity of species, including terrestrial and arboreal mammals, reptiles, amphibians, birds and bats.

Wildlife crossing structures can be planned, designed, built and managed with the sole purpose of facilitating the movement of wildlife (i.e. hereafter termed ‘dedicated’ wildlife crossing structures) or they can be crossing structures that facilitate the movement of wildlife as well as other functions, such as drainage or the movement of stock, people and machinery (hereafter ‘multi-use’ crossing structure).

4.2.2 PROPOSED WILDLIFE CROSSING STRUCTURES – OVERVIEW

The highway upgrade project passes through a complex and varied environment that includes:

- areas that provide important habitat for wildlife, such as Soysambu Conservancy, Marula Estate, KWSTI, Lake Naivasha, and other conservation areas
- numerous urban areas and towns
- agricultural areas that are used for a diversity of uses at different intensities, including irrigated and non-irrigated cropping, vegetable growing, stock grazing and livestock herding
- forestry and timber production, particularly to the north and south of the project.

Dedicated wildlife crossing structures will primarily be built where the highway passes through conservation areas with secure land tenure and long-term conservation of wildlife is assured (refer to Section 3.4.7).

The multi-use crossing structures will primarily be built within the conservation areas as supplemental/incidental crossing opportunities as well as in areas outside conservation areas where wildlife may occur in typically lower quality habitat

Further details of the location and design of each crossing structure is provided in Section 7 of this report.

4.3 LAND BRIDGE (VEGETATED OVERPASS)

4.3.1 BACKGROUND

One of the most effective techniques to facilitating the movement of wildlife across linear infrastructure is with land bridges, which allows animals to pass above the infrastructure via a vegetated overpass (see Figure 4.1 and Figure 4.2). This is achieved by building a bridge or arch over the road, placing soil on it and allowing vegetation to grow and to connect to vegetation on both sides of the road. Land bridges are more expensive than underpasses, but when well-designed and maintained they allow for seamless landscape integration and movement of wildlife, plants and ecosystem processes across the road. Land bridges are most cost-effectively employed at locations where the infrastructure is within or partially within a cutting, however they can also be built where the road is at-grade.

Figure 4.1. Vegetated landbridge for wildlife built using arches (left) and as a bridge (right).

Figure 4.2. View on the top of land bridges that are 50 – 70 m wide in The Netherlands and France, showing rows and piles of tree stumps and shrubs within grassy areas which provide habitat and 'furniture' for a range of different species and enable views across the bridge.

4.3.2 DESIGN OF LANDBRIDGES

The vegetated land bridge on this project is proposed for areas supporting Giraffe or areas that Giraffe use as dispersal or migration corridors, as both KWS (2019) and species experts have suggested that landbridges are the best approach for this species, followed by tall underpasses. Landbridges are also the most effective approach to facilitating the movement of almost all other species, including sensitive birds and bats that avoid crossing above the road itself, or may be prone to WVC due to their habitat of low-flying.

There are no examples of landbridges in Africa to guide the design of landbridges on this project, however the following is relevant:

- The Kenya Wildlife Service originally proposed in 2017 that the landbridges should be 100 m wide (KWS 2017), which The Biodiversity Consultancy supported in their 2018 report (Bennun *et al.* 2018)
- The recommended minimum width of landbridges in Europe is 40 – 50 m (IENE 2003), and the minimum width of a landscape bridge is > 80m.
- The (US DOT FHA 2011) recommend a minimum width of 40 – 50 m, and a recommended width of 50 – 70 m
- The Indian guidelines recommend that land bridges are up to 70 m in width.
- The German guidelines recommend wildlife overpasses be 50 m wide.
- All guidelines and prescriptions from around the world, and indeed almost all reviews of the rates of use of crossing structures by wildlife have shown that wider landbridges typically have higher rates of use by more species.
- The species experts have advised that Giraffe are sensitive species and likely to be disturbed by traffic noise, lights and the visual disturbance and this may hinder their use of crossing structures.
- Given the height of their heads at 4.5 – 5.5 m, wider overpass structures with opaque fencing are required to provide a central core area that is quiet and free from disturbance
- Soysambu is considered critical habitat for the Nubian Giraffe, which is Critically Endangered according to the IUCN Red-list and Marula Estate is home to the Endangered Masai Giraffe. However, both conservancies are privately owned and there is no binding long-term commitment to the conservation of wildlife, and thus expensive landbridges are not justified at these locations (refer to Section 3.4.7 for more details). In addition, the managers of Soysambu have advised they do not want a landbridge because they do not want to encourage the free movement of wildlife to the east of the highway because the area of habitat is relatively small, in close proximity to humans, has been sold in part for development and thus has an elevated risk of poaching.

There is one landbridge proposed for this project across the A8South with the following design parameters:

- 40 m wide (measured as usable width at its narrowest point)
- Noise and light screens on the edge of the landbridge above the road and for 100 – 200 m on all approaches, with feasibility to be confirmed during detailed design
- Vegetated with native shrubs and trees and include optimal habitat for giraffe in the middle of the overpass
- Be free of any human or livestock activity that may disturb and discourage use by Giraffe

Further details for the design of land bridges are provided in Table 4.1.

The number and location of landbridges for this project are given in Table 7.1

Table 4-1. Detailed design elements for land bridges

DESIGN ELEMENT	CONSIDERATIONS
Efficacy	— Proven in Europe, North America and Asia for numerous large species. Likely effective in Africa.
Target species	— Many species of terrestrial wildlife, including mammals, reptiles, amphibians and invertebrates, as well as birds and bats
Design, dimensions and construction materials	— At least 40 metres of usable space wide so Giraffe are able to use without disturbance from traffic. — Soil depth to be a minimum of approximately 2 m, as required to support the same type of vegetation growing adjacent to the highway and suitable for grass, shrubs and scattered trees — Gently graded vegetated ramps / approaches, ideally 5:1 (horizontal to vertical). — Approach ramps to be hourglass-shaped, to encourage wildlife to access and enter the bridge — No artificial lighting within 500 m of land bridge — Construction method depends on topography (i.e. in a cutting or at grade), the length of the span and can include pre-cast concrete arches, cut and cover tunnels, or concrete bridges
Landscape position, fencing and landscaping	— Ideal when the road is in a cutting, but also feasible where the road is at grade — Install a minimum of 2 km of wildlife fencing in each direction wherever there is a risk that the target species may access the highway. Longer fencing may be required for wide-ranging species. — Avoid potential barriers across or near to landbridge, such as farm fences, roads — Vegetation on the bridge should match the adjacent vegetation or be specific for the target species, as well as include different bands of habitat (e.g. one side forested, the other more open grassland) depending on the target species — Allow vegetation adjacent to the road to grow to the landbridge, providing seamless transition from adjacent habitat to structure. — Noise and light screening and vegetation on edge of bridge and on approaches to the bridge are required to stop noise and light from oncoming vehicles. Soil berms on the bridge are not recommended due to the additional weight and the extra space they occupy, compared to screens
Furniture to encourage use and reduce the risk of predation	— Place logs, strategically placed piles of rocks or other habitat features that suit the target species on the landbridge to provide natural cover/shelter from predators and improve habitat suitability — Wetlands at the base of the approach ramps are recommended to deal with stormwater run-off and provide resources to attract wildlife to the bridge — Place structures at the entrances to the bridges that prevent unauthorised vehicle access but does not restrict wildlife movement
Maintenance	— Inspections should be undertaken in accordance with an approved Operational Environmental Managemental Plan (OEMP) and Standard Operating Procedures (SOP) that protects vegetation and habitat according to the ecological aims of the structure — Inspections to assess the structural integrity of bridge should be conducted at the same frequency as for normal bridge structures

	— Inspections to assess the ecological condition of the land bridge should be conducted annually for the first three years, and once every three years thereafter

4.4 WILDLIFE UNDERPASSES

Underpasses for wildlife come in a variety of shapes and sizes, ranging from very large viaducts to open span bridges, box and pipe culverts. Underpasses can be specifically for wildlife (i.e. dedicated underpass) or multi-use (i.e. human use such as drainage, livestock etc and wildlife). In almost all situations, dedicated wildlife underpasses are more effective than multi-use underpasses.

The original 2017 recommendations made by KWS specified that the underpasses must be 30 m wide and 7 m high (KWS 2017). The Schedule 2 (design Construction Standards) Execution Version lists 11 underpasses that were to be at least 20 m wide and 7 m high, with the height to allow use by Giraffe. The 2019 recommendations were significantly smaller, at between 5 and 7 m wide and 3.5 m high (Table 3.1). The underpasses proposed in this ESIA are built according to the target species of wildlife and whether they are dedicated or multi-use.

Two types of underpasses are proposed, namely open span bridges and culverts. The primary difference in the two options are size and construction technique, with bridges being wider and more open than culverts. Open span bridges are described in detail in Section 4.5 and culverts described in Section 4.6.

4.5 OPEN SPAN BRIDGES

4.5.1 BACKGROUND

Bridge underpasses can include single span bridges, as well as longer multi-span bridges or viaducts. Bridges and viaducts are typically employed where roads cross important habitats and wildlife populations, major waterways, steep valleys or areas prone to flooding. Bridges and viaducts are the most effective underpass option for wildlife because they are large and open, have a natural substrate and typically support more shrubs, logs and other cover than culverts. Wherever possible, bridge underpasses should be used instead of multi-cell culverts where wildlife movement is a high priority. As for other types of underpasses, larger and more open is always better because larger underpasses are typically used at higher rates by a greater diversity of species than smaller underpasses. Standard bridge designs can be easily modified to accommodate the movement of wildlife (e.g. Figure 4.3,Table 4.2).

Careful consideration is required in the design of bridge underpasses to ensure that scour protection (e.g. concrete, large rocks) does not interfere with the movement of wildlife. Where possible, there should be sufficient and separated space for water movement, wildlife movement and scour protection. The length of bridges may need to be increased slightly to allow space for wildlife movement on both sides of the waterway if the area required for scour protection is unable to be reduced.

The bridge underpasses installed as part of the SGR project range in width from 20 m to almost 2 km, and from just under 6 m to 12 m in height.

Figure 4.3. The Slaty Creek Bridge on the Calder Freeway in south-east Australia was designed to be higher and longer than required simply for drainage, to encourage wildlife movement. In this example, the vegetation has been planted underneath the structures, and tall trees retained between the two carriageways. This is an example of a very large bridge – most do not need to be this large. Photos Rodney van der Ree, WSP.

Figure 4.4. (Left) Example of a well-designed bridge underpass that is open, with a natural substrate and continuous vegetation compared to a poorly designed bridge underpass (right) with minimal space on both sides of the waterway and over-use of large rocks for erosion control that hinders the movement of many species. Photos Rodney van der Ree, WSP.

4.5.2 DESIGN OF BRIDGE UNDERPASS

Open span bridges are the optimal underpass for the movement of wildlife because:

- Bridge underpasses are larger than culverts and allow herds of animals to use them as a group
- Bridge underpasses are more ‘open’, thereby allowing sensitive species that don’t like enclosed spaces to use them and provides opportunities for prey species to avoid potential predators. Culverts can give a perception of being a tunnel, which some species avoid.

- With a large span, there is space in the underpass for different features, such as a line of logs, tree stumps or rocks to provide protection and shelter for smaller prey species from predators
- Bridge underpasses have a natural ‘floor’ (rather than a concrete base like culverts), which encourages more sensitive species to use them
- Bridge underpasses should be built as grade separated structures, allowing light and water to reach the ground and facilitate the growth of natural vegetation adjacent to and between each structure
- The light reaching the ground level between the structures increases light levels in the underpass, making it more inviting to more species

Further details for the design of open span bridge underpasses are provided in Table 4.2.

Table 4-2. Detailed design elements for bridge underpasses

DESIGN ELEMENT	CONSIDERATIONS
Efficacy	— Proven in Europe, North America and Asia. Evidence from SGR indicate also effective in Africa. If sufficiently tall, they may be suitable for Giraffe.
Target species	— Many species of terrestrial wildlife, including mammals, reptiles, amphibians and invertebrates, as well as birds and bats — If large enough and with appropriate furniture and vegetation, target species can include arboreal species, birds and bats
Design, dimensions and construction materials	— Bridge underpasses should be as tall and wide as possible to enable the movement of the widest diversity of species — Dedicated bridge underpasses for wildlife shall have a minimum clearance of 5 m and width of at least 20 m. Underpasses for Giraffe should be at least 7 m tall. — Where possible, use two separated bridge structures to allow light and water to penetrate and support vegetation growth. Install wildlife fencing between the bridge structures to prevent wildlife from accessing the road and people from accessing the underpasses. — Install noise and light screens on the edge of the bridge to reduce disturbance to wildlife passing underneath. Noise and light screens should also be considered for 100 m either side of each underpass to reduce disturbance to approaching animals — No artificial lighting within 500 m of dedicated wildlife bridge underpasses — Any use that could compromise the function of the underpass (e.g. movement of stock or machinery) should ideally be moved to another location, be restricted to a culvert installed next to the bridge underpass or strictly kept within a narrow portion of the bridge underpass. Grow screening vegetation between the farm access road and the wildlife movement to reduce disturbance for wildlife. — If the bridge crosses a waterway, wildlife movement areas should be on both banks of the waterway and ideally remain dry year-round except during 1:10 year flood events — Do not use large rocks for scour protection within the wildlife movement zone as this will discourage larger mammals from entering. If scour protection is required, use concrete or small rocks instead and increase the span of the bridge accordingly.

DESIGN ELEMENT	CONSIDERATIONS
Landscape position, fencing and landscaping	— Install a minimum of 2 km of wildlife fencing in each direction wherever there is a risk that the target species may access the road — Avoid potential barriers across or near to bridge underpasses, such as farm fences or roads
Furniture to encourage use and reduce the risk of predation	— Allow vegetation and habitat adjacent to the road to grow under the bridge structure, maximizing continuous protection and shelter across the road. Species selection for planting adjacent to and under bridges should take into account the needs of the target species, adjacent plant communities and risk of damage to the bridge structure. — Place logs, strategically placed piles of rocks or other habitat features that suit the target species underneath the bridge to provide natural cover/shelter from predators and improve habitat suitability — If the bridge underpass is combined with drainage, ensure fauna furniture is not washed away during floods
Maintenance	— Place structures at the entrances to the underpasses that prevent unauthorised vehicle access but does not restrict wildlife movement — Inspections to assess the structural integrity of bridges and viaducts should be conducted at the same frequency as for normal bridge structures — Inspections to assess the ecological condition of the bridge underpasses should be conducted annually for the first three years, and once every three years thereafter. Ecological inspections should also be conducted after every 1:20 year rainfall event — 6-monthly inspections are required to detect and exclude people from setting up camps under the bridges

4.6 DEDICATED WILDLIFE CULVERTS

4.6.1 BACKGROUND

Dedicated wildlife culverts are circular or box-shaped underpasses, typically made of concrete, that are primarily installed to facilitate the movement of wildlife under the linear infrastructure (Figure 4.5 and Figure 4.6). Dedicated wildlife culverts may occasionally allow the movement of water (e.g. during a 1:10 or 1:100 year flood event) but they are always optimised for wildlife and other uses are incidental. The use of dedicated wildlife culverts by people and livestock is discouraged due to the risk of disturbance to wildlife.

Box culverts are square, rectangular or arched-shaped culverts that are significantly more effective than pipes at facilitating the movement of wildlife. Therefore, box culverts should always be adopted in preference to pipes whenever possible. Box culverts and arches are more effective than pipes because they have flat bottoms and larger openings than pipes of the same height, and thus facilitate greater movement of wildlife.

Culverts are typically targeting terrestrial wildlife, including mammals, reptiles, amphibians and, if they are large enough or with appropriate features, they may permit some movement of certain species of birds and bats. The optimal size of a culvert is determined by the requirements of the target species of wildlife and are best suited where the road is already on fill. However, it is always better to install larger culverts than required because the majority of studies evaluating the effectiveness of underpasses from around the world indicate that larger (tall and wide) and shorter (length) underpasses are better than those that are smaller and longer.

Where possible, culverts should have a natural substrate and include furniture (e.g. logs and scattered rocks) to provide natural cover/shelter from predators and improve habitat suitability. Furniture features can be installed on the ground, attached to walls or built into the structure itself (i.e. bat roosts built into culverts).

The entrances to culverts should be kept as natural as possible, and the use of large rocks for erosion control should be avoided as this will restrict entry by some species. Wildlife culverts should be positioned in the landscape to be above drainage lines and flood levels as much as possible, as wet culverts are likely to deter terrestrial wildlife. Culverts for the movement of amphibians should remain as wet as possible to facilitate their movement.

Figure 4.5. Dedicated 3 m x 2 m (left) and 2 m x 2 m (right) culverts for wildlife. Culverts are smaller than open span bridges and present as a 'tunnel' to wildlife and are likely less effective than bridge underpasses for open-country species.

Figure 4.6. (Left) Interior of a recently constructed wildlife culvert, with a timber rail for scansorial and arboreal species. (Right) large arch culvert with logs and branches providing furniture for arboreal wildlife.

4.6.2 DESIGN OF DEDICATED CULVERTS

All dedicated culverts for wildlife are at least 3.5 m tall and 5 m wide, in accordance with the dedicated wildlife culverts proposed by KWS in 2019. These are proposed as intermediate or lower-priority crossings below the dedicated bridge underpasses in the important conservation areas. The effectiveness of box culverts at permitting the movement of larger species is less certain than for overpasses and open span bridges, and thus are considered as crossing structures for smaller species that prefer enclosed spaces, such as fossorial species or those that live in underground dens. Culverts are also considered as facilitating incidental crossing by a wider groups of species that will use smaller structures such as culverts only occasionally.

The use of dedicated wildlife culverts by people and livestock is discouraged, and adjacent culverts that are specifically for people and livestock are typically provided as an alternative to use of the wildlife culvert.

Dedicated box culverts are proposed at various locations along the highway – see Table 7.1 for more details. Enhancements to existing drainage culverts are also proposed to increase permeability of the overall project.

Further details for the design of open span bridge underpasses are provided in Table 4.3

Table 4-3. Detailed design elements of dedicated wildlife culverts

DESIGN ELEMENT	CONSIDERATIONS
Efficacy	— Proven
Target species	— Target species depends on the size of the culvert and includes many species of terrestrial wildlife, including mammals, reptiles, amphibians — If large enough and with appropriate furniture, target species can include arboreal species, birds and microbats
Design, dimensions and construction materials	— Culverts should be straight, and as wide, tall and short as feasible to allow unobstructed views through the culvert — If a culvert is to extend under a dual carriageway with a separated median, use two culverts with a break in the middle to allow light and water to penetrate. Install fencing between the two carriageways to prevent wildlife from accessing the road and from people accessing the culverts — No artificial lighting within 500 m of culverts
Landscape position, fencing and landscaping	— Encourage habitat for the target species to grow to the entrance of the culvert — Install a minimum of 500 m of wildlife fencing in each direction wherever there is a risk that the target species may access the highway. Longer fencing may be required for wide-ranging species. — Place dedicated wildlife culverts at known or likely movement pathways and mortality hotspots for the target species — Avoid potential barriers across or near to culverts, such as farm fences, roads
Furniture to encourage use and reduce the risk of predation	— The base of dedicated wildlife culverts should be as natural as possible, such as soil or mulch. Where possible, use culverts without a concrete base. — Scatter some large rocks, logs or artificial shelters within the culvert and at entrances to provide shelter for small wildlife from predators and to encourage use — Do not use large rocks at culvert entrances for scour protection, as this will discourage larger mammals from entering. If scour protection is required, use concrete or small rocks instead. — Include horizontal logs suited for the target species to provide alternative pathways and avoid predators.
Maintenance	— Inspections to assess the structural integrity of culverts should be conducted at the same frequency as for drainage culverts — Inspections to assess the ecological condition of the culverts should be conducted annually for the first three years, and once every three years thereafter. Ecological inspections should also be conducted after every 1:20 year rainfall event

4.7 MULTI-USE CULVERTS

4.7.1 BACKGROUND

The optimal approach to crossing structures is to design and manage them specifically for wildlife, and to keep wildlife passage and drainage separate. When this is not feasible, culverts and arches that allow the movement of water and wildlife are possible. However, these structures must be carefully planned and designed because wildlife movement is typically compromised when the focus of the design is primarily drainage. For example, it may not be feasible to keep furniture in multi-use culverts if they impede drainage or furniture and substrate may be washed away during flood events. However, drainage culverts that only infrequently have water for short periods of time provide important opportunities for incidental crossings and should be optimised. A significant problem in all types of multi-use culverts is standing water, which often occurs due to poor design and ponding (Figure 4.7).

Figure 4.7. Poor drainage and ponding can reduce the effectiveness of all types of culverts and they must be carefully designed, constructed and managed to effectively enable both uses. Photos (left) Rodney van der Ree WSP and (right) Scott Watson VicRoads.

For example, culverts that contain permanent water or water for many weeks of the year are less preferred by terrestrial wildlife than culverts which are dry or mostly dry for most of the year. Strategies to provide dry passage in drainage culverts include:

- Raising the height of the floor of the two (or more) outer cells so they remain dry except during major flood events (Figure 4.8)
- Lowering the height of the floor of the middle cell(s) to provide drainage during typical flow events
- Installing ledges and shelves above the height of the typical water level on the outer walls of the culvert(s) (Figure 4.9)

Figure 4.8. Example of multi-cell culverts on the Pacific Highway NSW where the middle cell is designed to take water flow year-round, with the outer cells remaining dry except during flood events. Photos Rodney van der Ree WSP.

Figure 4.9. Example of strategies that provide dry passage if the culvert contains standing or flowing water. Note that the concrete ledge and timbershelf in the left photo are still to be connected back to the adjacent habitat. Photos by Rodney van der Ree WSP.

4.7.2 DESIGN OF MULTI-USE CULVERTS

Multi-use culverts for people, livestock and wildlife have been designed with separate cells to keep wildlife separate from people and livestock. Two such structures are proposed for Kikuyu Escarpment Forest Reserve. Other multi-use culverts are for drainage and wildlife.

All drainage structures within the conservation and important biodiversity areas will be modified to act as multi-use culverts. In addition, all underpasses under the new carriageway at Marula Estate and Soysambu Conservancy will match or be slightly larger than what currently exists under the existing highway to act as multi-use underpasses.

Further details for the design of multi-use culverts are provided in Table 4.4

Table 4-4. Detailed design elements for multi-use wildlife culverts and arches. Note that this table should be read in conjunction with Table 4.3

DESIGN ELEMENT	CONSIDERATIONS
Efficacy	— Proven for some species, depending on the size, design and frequency of flooding
Target species	— Many species of wildlife, including smaller terrestrial mammals, reptiles, amphibians — Multi-use culverts are less effective for terrestrial mammals than dedicated culverts, unless the species are aquatic, semi-aquatic or don't mind wet feet.
Design, dimensions and construction materials	— If combined use includes people and livestock, accommodate them in a separate cell to avoid disturbance to wildlife. Use plantings or other screenings to limit disturbance upon approaches to the structure entrances. — If a single-cell culvert or arch, include a concrete ledge or shelf at a height above typical water levels that allows passage of the target species for most days of the year. Under typical flows, dry passage should be possible for ~80 - 90% of the time.

DESIGN ELEMENT	CONSIDERATIONS
	— If multi-cell culverts includes drainage, construct the two outer cells to be higher than the middle cell, which is the focus for water flow. The two outer cells should be high enough relative to normal flows to be dry approximately 90% of the time. — Shelves can also be used instead of concrete ledges or installed near the roof of the culvert, and flat/wide shelves are likely better than logs, depending on the target species. The attachment technique must be strong enough to withstand water velocity during high flows. — Do not use large rocks at culvert entrances for scour protection, as this will discourage larger mammals from entering. If scour protection is required, use concrete or small rocks instead.
Landscape position, fencing and landscaping	— The placement of multi-use culverts will be primarily influenced by hydrology requirements. Where possible, they should be adjusted to also coincide with known or likely movement pathways and mortality hotspots for the target species
Furniture to encourage use and reduce the risk of predation	— The base of multi-use culverts must be able to withstand high flow events, and thus concrete surfaces are suitable. — Due to its combined drainage purpose, any furniture that is not permanently attached will be washed away. Scattered large rocks in outer cells can be concreted into the floor of the culvert. Furniture should not present a blockage risk or significant impediment to water flow during flooding — Include horizontal logs suited for the target species to provide alternative pathways and avoid predators.
Maintenance	— Inspections to assess the structural integrity of culverts should be conducted at the same frequency as for drainage culverts — Inspections to assess the ecological condition of the culverts should be conducted annually for the first three years, and once every three years thereafter. Ecological inspections should also be conducted after every 1:20 year rainfall event.

4.7.3 DESIGN OF MULTI-USE PIPE CULVERTS

Multi-use pipe culverts are less effective for most species than multi-use box culverts and are not recommended for the movement of wildlife. At best, they may provide incidental connectivity for some wildlife. If multi-use pipe culverts are to be implemented, follow the same guidelines as for multi-use box culverts (Table 4.4).

4.8 CONNECTIVITY FOR ARBOREAL SPECIES

4.8.1 BACKGROUND

Arboreal species spend all or some of their time living in and moving between trees (Soanes and van der Ree 2015). The loss of trees across roads creates gaps in the connectivity of tree canopies, reducing or eliminating movement of arboreal species. This effect is the most severe for strictly arboreal species that rarely or never come to the ground and for those that are at high risk of predation when on the ground.

Arboreal species are often small in size, and historically were rarely considered in roadkill and connectivity mitigation. However, mitigation for these species has expanded rapidly in the last decade, and is becoming widespread across the world, including in Asia, Europe, North America, South America, Africa and Australia.

4.8.2 DESIGN OF ARBOREAL CROSSING STRUCTURES

Arboreal crossing structures include maintaining or restoring natural canopy connectivity and the installation of canopy bridges.

Canopy connectivity is where tree canopies are retained during construction or encouraged to grow after construction and provide a continuous or near continuous connection above the road. Achieving canopy connectivity is very difficult with 4-lane dual carriageway roads because the size of the gap usually exceeds the width of tree canopies and are thus not a viable option in this project.

Canopy bridges are a lightweight structure suspended above the road from poles or trees that connects woodland or forest habitat on either side of the barrier. Canopy bridges are typically used for arboreal mammals, but can also include arboreal reptiles. Canopy bridges vary in design, but include single strands of rope or rope-like materials, rope ladders, fabricated aluminium structures, timber poles and other similar materials. Key considerations when designing canopy bridges are that the target species is physically capable of climbing on the structure, that it is stable over the span of the road and requires minimal maintenance.

The target species for canopy bridges are arboreal mammals, such as Syke's, Vervet and Colobus Monkeys, and potentially arboreal reptiles, such as chameleons.

A design workshop for the canopy bridges for this project was held with primatologists and ecologists with expertise in roads and primates from South Africa, Kenya, Brazil and the USA. The workshop addressed design considerations, location, target species and other relevant factors. There was a consensus on the important need for canopy bridges, as well as uncertainty about the optimal design and thus the need for rigorous testing of whatever crossing structures are installed. The following design considerations are based on the results of trials of canopy bridges around the world and the topics discussed at the workshop.

Canopy bridges should be a minimum of 2 m above the height of the tallest trucks and are usually suspended from two treated timber poles or other support structures. They can also be attached to trees however assessing the structural integrity of trees at installation and over time is more difficult than for timber poles. Timber poles are probably better than steel or concrete poles because they are more similar to trees and probably easier to climb, however alternatives to timber should be considered in areas with high termite activity. Furthermore, access from the ground can also be facilitated with netting or other structures that come to the ground. Both timber bridges and rope ladders have been used successfully for primates in Kenya and South Africa (Donaldson and Cunneyworth 2015; Linden *et al.* 2020), although neither study spanned a 4-lane highway.

The width of the A8 duplication is problematic as the longest canopy bridges in Kenya and South Africa span relatively narrow two-lane roads and thus the behavioural willingness of primates to cross 4-lanes is unknown. From an engineering perspective, a 4-lane span is feasible, as single-span canopy bridges in Australia are up to 80 m in length. The inclusion of poles in the centre median was suggested during the canopy bridge workshop, however this may allow primates to climb down to the road, and unless this can be prevented, it is not recommended. Furthermore, the centre median will consist of concrete Jersey barriers, and is thus not suitable for wildlife to access.

Two important considerations in the design of the canopy bridges is that they must accommodate the weight of the primates and take into account the use of the bridges by multiple individuals. While baboons are not necessarily a target species for all bridges (as they will also use underpasses, as observed under the SGR in Tsavo National Park), designing the bridges to support multiple adult male baboons (up to 20 kg each) will ensure adequate capacity for all other species. An additional design criteria is that larger-bodied animals do not fall off as large trucks pass underneath at >100km hr^{-1}. A flattened 'U' shaped design currently being tested in South America looks very promising Figure 4.12 and is recommended for further testing on this project.

The canopy bridge should be as short as possible and be positioned within good-quality habitat for the target species. Both ends of each bridge should be tied back to at least two, and preferably three large trees to improve access and increase rate of use by wildlife.

Connecting the canopy bridges back to multiple trees builds in redundancy if some of the feeder trees collapse. Strategic revegetation around the poles and leading up to the poles is required to increase their medium-term connection to adjacent habitat. Further identification of habitat for primates and other arboreal animals is required to confidently identify optimal locations.

Poles should be accessible with an elevated work platform for inspections and maintenance and to install and maintain cameras or other monitoring equipment. A gravel hard stand beneath each pole will enable access during wetter months of the year.

A total of eight canopy bridges are proposed where the project passes through forested areas which support arboreal animals. The specific locations have not yet been identified, but will include the Kikuyu Escarpment Forest Reserve on the A8 and where the A8 South passes through the Kikuyu Escarpment Forest Reserve. Two designs of canopy bridge shall be installed as an experimental trial to test the efficacy of each design, most likely a flat ladder and a U-shaped netting. See Table 7.1 for more details.

Further details for the design of canopy bridges is provided in Table 4.5.

Figure 4.10. Canopy rope bridge across a highway (left) and on top of a land bridge (right), both in Australia

Figure 4.11. Example of the 'Squirrel Bridge' by Animex in the UK (left), an adapted overhead sign structure in Japan (middle) and simple pole structures that can be fitted to culverts and other structures. The optimal design for the diversity of arboreal animals on the A8 is yet to be determined.

Figure 4.12. Design of canopy bridge being tested for use by primates in South America and proposed for further testing on the A8 and A8South Project. This should be tested against other potential designs to evaluate use and effectiveness. Design by Fernanda Abra, ViaFauna, Brazil.

Table 4-5. Detailed design elements of canopy bridges

DESIGN ELEMENT	CONSIDERATIONS
Efficacy	— Proven in Australia, Asia, South America and for some species in Africa
Target species	— Arboreal and some semi-arboreal mammals, reptiles and amphibians
Design, dimensions and construction materials	— Consultation with local experts and field-testing is required to test different designs for relevant target species. A promising design is shown in Figure 4.12. — Rope ladders made of UV-stabilised marine-grade silver rope attached to steel cables are used in Australia for possums and gliders. — Timber structures such as bamboo poles may be suitable if supported to span the width of the road. — Bridges for monkeys in Malaysia have used sections of old fire-hose. — Rope ladders were successful for primates at Diani Beach Kenya and Brazil — The structure must be a minimum of 2 m above the height of the tallest trucks — The supports can be timber poles or trees, with poles recommended at locations where there are no suitable large trees or where the risk of damage to high-value understorey vegetation during installation or maintenance is low — Use rough-sawn timber poles where possible and avoid steel poles and smooth timber poles because they are more difficult or impossible for an animal to climb, unless a rope or netting ladder extends to the ground — In most situations, poles need to be treated to prevent rot and termite damage and extend lifespan of the pole. Non-treated poles can be used where risk of rot and termite damage is low. The cross-arm assemblies should be non-treated hardwood as this is where animals will spend most of their time.

DESIGN ELEMENT	CONSIDERATIONS
	— The ends of canopy bridges should be tied back to a minimum of two and preferably three or more large trees to increase access by wildlife — Identify important access trees adjacent to the road during detailed planning and design and ensure these are protected and retained during construction — Include hard stands at the base of poles to enable access for maintenance during wetter months — Shorter canopy bridges are better than longer ones — No artificial lighting within 500 m of canopy bridges
Landscape position, fencing and landscaping	— It is not possible to build effective fences for arboreal mammals and canopy bridges because many species are adept and excellent climbers. Therefore, install in high quality habitat, along existing corridors or movement paths and at natural pinch points — Additional poles, canopy bridge and/or tree planting may be required to connect the canopy bridge to adjacent vegetation
Furniture to encourage use and reduce the risk of predation	— Rope-ladders are more stable and provide more opportunity for wildlife to avoid aerial predators than single strands of rope. Single strands should never be used to span above the linear infrastructure — Depending on the target species, consider including shields and refuges to provide protection from aerial predators, ensuring it doesn't compromise function of the canopy bridge.
Maintenance	— Annual inspections of pole integrity, sagging or twisting of the rope ladder, connection to feeder trees and condition of predator protection is required

4.9 WILDLIFE FENCING

4.9.1 BACKGROUND

The most effective method to reduce rates of WVC and mortality of terrestrial wildlife is to install enough appropriate fencing that prevents them from accessing the highway. A recent review of the international scientific literature showed that roadside fencing that is correctly designed, installed and maintained can reduce rates of mortality by an average of approximately 50%, and up to almost 100% in some situations (Rytwinski *et al.* 2016). Fencing that is effective at reducing rates of collision with wildlife necessarily increases the barrier effect because they are designed to keep animals off the road. Therefore, wildlife fencing is typically recommended where crossing structures can also be installed.

Wildlife fencing is used to reduce the rate of WVC by preventing wildlife from entering the highway and to increase landscape connectivity by funnelling wildlife towards the crossing structures (van der Ree *et al.* 2015a). Wildlife fencing must be designed specifically for the target species to maximise its effectiveness, which in the case of this project includes small to large mammals, amphibians and reptiles. Primates in the study area are excellent climbers and are likely able to climb all designs of fencing currently available, and thus no fencing for primates is feasible or recommended. At best, the canopy bridges should be easier to climb than fences, and over time the primates will hopefully learn that they are a safer means to cross the road than by crossing the road at ground level.

The length of wildlife fencing at a crossing structure will depend on the extent of habitat in the area, the movement patterns of the target species and the occurrence of other roads accessing the highway. Where possible, wildlife fencing should be continuous through important habitat in order to prevent wildlife from accessing the road at fence endpoints. Wildlife fencing that also acts as a property boundary fence should be connected to boundary fencing, thus providing a continuous single fence.

The ends of wildlife fencing need a specific treatment, and where possible, should be angled away from the highway to encourage wildlife to turn back, rather than simply have them move around the fence end and onto the highway. Where possible, wildlife fencing should continue past the habitat and into adjacent non-habitat before being angled back. Fencing can also terminate at natural barriers to movement, such as cliffs, rocky areas or other geographical features that limit movement of the target species.

Ensure wildlife fencing is strongly and tightly attached to the crossing structures so that animals are unable to squeeze between the fence and (for example) the abutment walls and access the highway.

Other important considerations include whether it is electrified, fence height, mesh size and whether the fence needs to be buried to prevent burrowing animals from digging underneath it. Floppy-top fencing is not recommended because it has higher maintenance requirements compared to straight fencing. Sheet metal or fine mesh may be required along the bottom to prevent smaller wildlife (e.g. frogs, reptiles, small mammals) from passing through and accessing the highway.

Wildlife fencing will usually need breaks in it to allow vehicles to access the highway, such as at intersecting roads or property access points. Where these occur, effort must be made to prevent animals from accessing the highway, such as through the use of gates, cattle grids across the intersecting road, or wildlife fencing that is run up the intersecting road for a few hundred metres. Poorly installed gates can provide a point of egress for fauna to access the highway reservation, so gaps underneath and between gates need to be minimised to prevent fauna going under them.

Where possible, wildlife fencing should be combined with property fencing to reduce the number of fences required and minimise installation and maintenance costs.

Wildlife inevitably breach fencing and so escape mechanisms are required to allow them to leave the fenced highway reservation. Further information about escape mechanisms is given in Section 4.10.

Figure 4.13. Electric fencing with wire mesh at the base and dug into the ground (left) is a standard and effective approach to controlling the movement of wildlife in East Africa, and will be installed in continuous lengths in Marula and Soysambu and in shorter

lengths at crossing structures. Photo on right shows cattle grids on low-volume roads which if wide enough can prevent wildlife movement. Modified cattle grids and/or electrified mats are proposed for use where wildlife movement across gates or access roads is required.

Figure 4.14. Care must be taken to avoid gaps under wildlife fencing, especially at gates and where fencing is attached to crossing structures. Photo Josie Stokes WSP.

Figure 4.15. Barbed wire presents a significant risk of entanglement and mortality to wildlife, such as this Squirrel Glider, and should never be used near crossing structures for at-risk species. Photo Rodney van der Ree WSP.

4.9.2 DESIGN OF FENCING

- Various types of fencing already exists along one or both sides of different sections of A8 and A8 South, including game fencing where A8 passes through Marula Estate and Soysambu Conservancy. Existing fencing that is effective will be retained where possible, and additional fencing to prevent wildlife from accessing the highway and to funnel them towards the crossing structures will be installed for the full length of where the highway passes through Soysambu Conservancy, Marula Estate and other important habitats, as well as in short lengths (up to 2 km) at all dedicated wildlife crossing structures which are not fully fenced.
- Fencing will be as suggested by KWS (2019) (i.e. 8-strand electrified, mesh to a height of 600 mm and buried to 500 mm to prevent digging animals). The height will be re-assessed prior to construction to ensure no species in the area can jump over.
- Jump outs and other escape opportunities will be provided within Marula and Soysambu to enable wildlife to escape from the highway reservation and re-enter the two conservation areas
- There will only be limited opportunities to directly access Marula and Soysambu from the highway because these locations are the weakest points in the fence and if damaged or poorly maintained they are the locations where wildlife may access the highway reservation. Such access points will be controlled through the use of cattle grids, electrified mats, automatic gates and be positioned as far from wildlife habitat as possible

Table 4-6. Detailed design considerations for wildlife fencing

DESIGN ELEMENT	CONSIDERATIONS
Efficacy	— Proven for many target species, when designed accordingly
Target species	— Designs exist for most terrestrial species including small to large terrestrial mammals, reptiles, and amphibians — Not effective for gliders as they can glide above the fence from adjacent trees and many arboreal species can climb over — Always consider unintended impacts to other species, such as entanglement and restriction of movement
Design, dimensions and construction materials	— Ensure wildlife fences are attached securely to crossing structure, such as abutment walls, ensuring wildlife are funnelled directly to crossing structure and are unable to squeeze between crossing structure and fence — Height, mesh size or impermeable material, depth buried or use of skirt is target-species specific — Mesh should not be plastic-coated as this will melt during fires — Consider placement and strength of fence in areas subject to flooding — Wildlife fencing should be integrated with property fencing to save costs, and avoid unnecessary parallel fencing — Where possible, wildlife fencing should be continuous in areas of habitat for the target species and extend past the suitable habitat into adjacent areas of non-habitat — Wildlife fences should be installed on both sides of the highway, however one side may be adequate if the source area for the target species of wildlife are only on one side — Wildlife fencing should typically include a 'return', an angled section of fence to encourage wildlife to turn backwards rather than move around the fence end and access the highway. Fence ends can be integrated with other infrastructure such as boundary fencing or topographical features such as cuttings — Gates must be installed as close to the ground as possible
Landscape position, fencing and landscaping	— Manage vegetation on the habitat side of the wildlife fence according to the target species and their climbing ability — A minimum clearance zone of 3 m between the wildlife fence and adjacent vegetation is required to allow movement of maintenance vehicles
Furniture to encourage use and reduce the risk of predation	— Ensure appropriate escape mechanisms (Section 4.10) where wildlife fencing is continuous for lengths that exceed half of the typical home range of the species — Escape mechanisms include one-way gates, escape ramps and drop-down poles. One-way gates require additional maintenance and are to be avoided
Maintenance	— Wildlife fencing should be inspected and repaired every 2nd year and after major flood events or wildfires

4.10 FENCE ESCAPE OPTIONS

4.10.1 BACKGROUND

Wildlife inevitably breach fencing and escape mechanisms are required to allow them to leave the highway reservation. Escape mechanisms are particularly important in areas with long-lengths of wildlife fencing; elsewhere wildlife can move to the ends of fencing to leave the highway reservation. The length of wildlife fencing where escape mechanisms are required is species-specific and dependent on their typical movement parameters. As a guide, escape mechanisms are likely required where the length of fencing exceeds their typical maximum home range length. These escape mechanisms include one-way gates or jump outs, where animals can jump down and out of the highway road reserve but not back into it (Figure 4.16). One way gates are not recommended because they have jammed open or closed in installations overseas and thus require additional maintenance to ensure they operate effectively.

4.10.2 DESIGN OF FENCE ESCAPE OPTIONS

The design of effective escape mechanisms for East African wildlife has not been investigated and can not be specified with any certainty without research. The project will undertake targeted research to identify the species most likely to require escape options and test some preliminary designs for inclusion in the final design. However, the following features are likely suitable design options for this project:

- The simplest approach is probably where wildlife can jump down and out of the highway reservation, such as where the road is built up on fill and has steep batters (i.e. a jumpout). These could be co-located with underpasses where the road must be built up to provide space for culverts of bridge underpasses.
- A retaining wall at least 2 m tall (e.g. Figure 4.16), potentially with a cross-bar structure to prevent animals from climbing up or jumping up may be effective
- Jumpouts should be placed in locations along the highway where wildlife may naturally be attracted, such as water bodies or suitable food. The attractant should be outside the road reservation to encourage wildlife to leave the reservation, and not enter it.
- Jumpouts will be required on both sides of the highway so wildlife can access the jumpout without being required to cross the road multiple times.
- The suitability and effectiveness of different jump-out designs should be tested prior to construction and/or constructed in such a way that modifications can be implemented relatively easily and cheaply.

Figure 4.16. Example of one-way gates (left) and jumpouts (middle) from the USA and Pacific Hwy NSW (right) to allow animals that breach wildlife fencing and find themselves trapped between the fence and the highway to escape. A limitation of one-way gates is that they can become stuck in the 'open' or 'closed' positions and become ineffective. Jump-outs must be designed and tested for the target and non-target species to ensure they are unable to climb up and into the highway reservation. Photos Rodney van der Ree WSP.

4.11 MITIGATING LIGHT, NOISE AND VISUAL DISTURBANCE

4.11.1 LIGHT

Design principles for road (and other) lighting are detailed in Table 4.7. These principles should be followed for the entire road alignment. The primary approach to mitigating the impacts of artificial light at night from street lights will be by not installing any street lights within areas of high quality wildlife habitat.

The table does not address vehicle lights. Screening will be required to shield light, particularly headlights, and noise from the vegetated land bridges and other important crossings.

Table 4-7 Lighting principles

	LIGHTING DESIGN PRINCIPLES	KEY REFERENCES
Siting of lights	— Utilise lighting only where necessary – consider white lining and 'cats' eyes' in other location. Use the minimum amount of light (lumens) required — Site lighting columns well away from sites of ecological value – we recommend a minimum of 500 m to landbridges and 250 m to other crossings. — Consider the height of lighting. Generally, a lower mounting height is preferred (although not always, this should be determined by a lighting designer with experience minimising impact on sensitive receptors).	— Interim Guidance: Artificial lighting and wildlife - Recommendations to help minimise the impact of artificial lighting (Bat Conservation Trust Undated). — Florida Fish and Wildlife Conservation Commission – Wildlife Lighting Criteria

	LIGHTING DESIGN PRINCIPLES	KEY REFERENCES
Fixtures	— Install fully shielded lights or fixtures to direct light down to where it is needed only, and to minimise light spill onto sites of ecological value. — Avoid using reflective surfaces under lights.	(Florida Fish and Wildlife Conservation Undated). — International Dark-sky Association website (International Dark-Sky Association Undated).
Wavelengths	— Use narrow-spectrum light sources to lower the range of species affected by lighting — Avoid white or blue wavelengths – where white light sources are required they should be of a warm colour temperature (definitely <4,200 kelvin, preferably <3,000 kelvin). — Minimise emission of ultra-violet light. — Utilise long wavelength light sources.	
Temporary fencing	— Should vegetation be utilised as a screening measure, install temporary fencing until vegetation is sufficiently mature.	

4.11.2 NOISE

The impacts of construction and operational noise on wildlife will be mitigated by:

1 Ensuring noise control protocols that are adopted in areas with sensitive receptors (e.g. schools, hospitals, residential areas) are also followed in areas of high-quality habitat for wildlife. There are currently:

   a Day time (7h to 22 h): ambient noise before work + 3 dBA

   b Night time (22h to 7h): IFC criteria (45 dBA) + 2 dBA

2 Where these noise control protocols are unable to be followed in high quality habitat, the construction noise should be ‘ramped up’ over a few days, allowing animals in areas immediately adjacent to the construction to move away temporarily, should they wish to do so.

3 Peaks in traffic noise are expected to decrease slightly due to a reduction in the acceleration and deceleration of traffic attempting to pass each other on the currently single-lane road. The slight increase in general operational traffic noise is not expected to be a major additional impact compared to current levels and no further mitigation is required, except at wildlife crossing structures.

4 Subject to feasibility to be determined during detailed design, the impacts of traffic noise will be mitigated primarily through the use of noise walls and/or soil berms at the dedicated wildlife crossings (see Section 4.11.3), and to a lesser extent through the use of vegetation plantings and light walls in lower priority areas.

4.11.3 VISUAL DISTURBANCES

The impacts of visual disturbance on wildlife shall be mitigated in areas of high-quality habitat for wildlife through:

1 The planting and maintenance of screening vegetation along the road edge / fenceline, limiting the distance that the road is visible from and the distance that vehicle headlights can penetrate into adjacent areas

2 Construction of noise and light screens at wildlife crossings and the approaches to the wildlife crossings. This is particularly important at the high priority crossings to enable more sensitive wildlife species to approach and use the crossing structures. Further details of the noise and light screens is given in Sections 4.3 to 4.7

4.11.4 OTHER DISTURBANCES

Other disturbances to wildlife occur through the use of WCS by people to cross the highway or the use of underpasses or areas close to WCS by people for shelter. Further disturbance or impacts occur through poaching and bushmeat hunting.

The impacts of people using WCS for crossing the road or shelter will be avoided and mitigated by:

1. Allowing people to use specific structures and discouraging them from using the dedicated WCS. Where use is combined, people and livestock will either be restricted to an adjacent culvert or restricted to a narrow pathway on one side of the crossing structure that is screened from the wildlife area. Large rocks or other structures will be strategically placed on the landbridges to prevent vehicle access.
2. Placing many of the WCS in areas of protected land that has wildlife conservation as a primary goal will help to ensure that the WCS and adjacent lands will be managed primarily for wildlife, and managers will be provided with specific instructions that detail allowable activities near to each WCS.

Poaching and bushmeat hunting is not expected to increase as a result of the highway upgrade because it is already a well-travelled road and traffic volume will increase after construction, further discouraging illegal activities. Nevertheless, poaching and bushmeat hunting will be discouraged by:

1. Constructing wildlife fencing in the conservation areas that limit easy access by poachers and securely attaching the fencing to the WCS
2. Regular and frequent monitoring of fencing by managers of adjacent conservation lands and the Kenya National Highways Authority (KeNHA)

4.12 SIGNAGE

Signage to alert motorists to the presence of wildlife and the risk of WVC has limited success at modifying driver behavior because motorists soon ignore the signs. This occurs for a variety of reasons, including that drivers rarely see wildlife near such signs and therefore do not equate a high risk with such signs, especially the standard warning signs (i.e. with black stencil of wildlife) (i.e. Figure 4.17). However, signs that are more interactive or informative, such as those that are triggered when wildlife are detected nearby, or signs that are regularly updated with the number of recent WVC appear to result in an albeit small reduction in vehicle speed for a longer period of time (Huijser *et al.* 2015).

Signage warning drivers of the risk of WVC will be installed along the highway however it will not be relied upon as a primary method to reduce the rate and severity of WVC. Fencing and crossing structures will be the primary method, and signage a secondary method.

Figure 4.17. Standard wildlife warning signs are largely ineffective at reducing the rate of wildlife-vehicle collision and are therefore an additional and secondary approach to reduce WVC on this project

5 MANAGEMENT AND MAINTENANCE OF MITIGATION MEASURES

The ongoing management of wildlife crossing structures is critical to the long-term success of the project and the ongoing survival of wildlife. The management of the crossing structures must:

1. Prevent people from using the structures for shelter, storage of equipment or any other use that may discourage wildlife from using them to cross the highway. Particular focus and effort must be given to prevent people from using the structures as locations to poach or hunt wildlife for meat. The design and position of wildlife fencing at crossing structures is a key determinant (see Section 4.8)
2. The crossing structures must be managed for their primary intended purpose, which is primarily wildlife passage for the dedicated crossing structures and a combination of uses, including wildlife movement, in the multi-use structures.
3. The maintenance activities must include an assessment of the structural integrity of the wildlife crossing structures and fencing, as well as the ecological condition and function. Inspection and maintenance of the ecological condition means:
   - Ensuring the vegetation on the approaches to the crossing structures and on the land bridges are suited to the target species
   - Avoid excessive clearing of soil and other debris within underpasses which may reduce the ecological suitability of the structure
   - Ensuring additional barriers, such as fencing, tracks and roads are not built in front of crossing structures, limiting access to the structure

6 MONITORING AND EVALUATION

The monitoring and evaluation of the use and effectiveness of the various mitigation measures deployed on this project is critical to adaptively managing the mitigation measures to achieve successful biodiversity outcomes and also improving the design of future road, rail and other linear infrastructure projects.

It is beyond the scope of this report to specify in detail the methods and study design that will be used to evaluate the use and effectiveness of the different mitigation measures. A detailed monitoring and evaluation plan will be prepared prior to the commencement of construction of this project. What follows is a brief outline of some of the questions, methods and study designs that should be considered. A key guiding principle in designing the monitoring and evaluation program is a focus on gathering robust and reliable evidence to confidently answer important questions about use and effectiveness. Further information to guide the monitoring and evaluation are provided in (Van der Grift *et al.* 2015; Van der Grift and van der Ree 2015; van der Ree *et al.* 2015b).

The proponent will establish a reference and implementation committee with representatives from KWS, KenHA, the adjacent conservation land managers, relevant wildlife conservation NGOs (e.g. Giraffe Conservation Foundation, Ewaso Lions and Grevy's Zebra Trust, Endangered Wildlife Trust) and ecologists with expertise in road ecology and linear infrastructure studies to develop and implement the monitoring and evaluation program. This committee should commence in the pre-construction period. Importantly, this highway project is an excellent opportunity to support post graduate research programs at a Masters and PhD level to do research on the impacts of highway upgrades and simultaneously meet any reporting requirements.

The proponent should commit to at least five years of detailed evaluation of both the rate of use of crossing structures and their effectiveness at achieving population outcomes for wildlife. The rate of use will be measured through the use of cameras deployed at both entrances to each WCS as well as facing the approaches to the crossing structures to determine the relative abundance of species to use the structures. This will enable an evaluation of the suitability for use of crossing structures by measuring the abundance of animals that are nearby and may use the structures, as well as those that approach and turn around.

These studies will continue for at least five years, and consideration will be given for longer durations if key species are yet to use the structures. Studies from Europe and North America have shown that a period of five to 10 years is required for some species to use WCS.

The monitoring will also quantify the rates of WVC in order to assess the effectiveness of fencing for all species of wildlife. Roadkill monitoring will not be used to evaluate the WCS, just to assess the effectiveness of fencing. Roadkill monitoring will be undertaken at two scales – for the first five years monitoring will be through standardised surveys by RVHL road maintenance crews following specified protocols (e.g. Collinson *et al.* 2014). After that, the RVHL road maintenance crews will record all roadkill that they clean up, plus any they incidentally observe during routine maintenance tasks. Data collected will be a combination of the results of the drive-by surveys as well as records of any collisions they attend. All data will be collected using an appropriate mobile phone application and regular training for the staff to identify species will be provided. Unfortunately, there is no baseline roadkill data against which future roadkill rates can be assessed – however the information collated to date indicate that rates of roadkill are currently low.

The population-level effect of the crossing structures is an important measure of success because it demonstrates how well the package of mitigation works is contributing to conservation benefits for the species. The scope and cost for this work is difficult to specify without further investigation of existing data sets and capacity of suitable partners to undertake this research. The project should set aside some money on an annual basis for the first ten years to contribute to research projects that investigate the population-level effects of the road and mitigation and use this commitment to leverage additional funds from a range of partners and donors to undertake this work. This approach is using funds for research as an additional compensatory tool to improve outcomes on this project and equally importantly to improve the planning, design and implementation of future road and rail projects in Kenya and Africa more generally. There are a range of questions and methods that could be employed to assess population-level success, including:

- Rates of movement and purposes of movement across the highway. This could be done for a select group of species that are of conservation concern or are expected to be representative of other species. A good example of one approach to this was the tracking of Elephants around the SGR in Tsavo National Park (Okita-Ouma *et al.* 2021).
- Rate of gene flow across the highway for certain species, such as Giraffe. This should be implemented for species for whom gene flow is a concern or where measurements of gene flow are expected to yield important data. These studies should be done in collaboration with relevant research centres or NGOs (e.g. Giraffe Conservation Foundation if Giraffe are studied)
- Changes in the size of the population on one or both sides of the highway. This can be cost-effectively implemented at Soysambu and Marula as these areas undertake regular aerial censuses of their wildlife populations anyway
- Changes in the rate of survival or longevity of key species, which require the marking and identification of individual animals and following them over time.

A key consideration in all monitoring and evaluation programs is to have a scientifically robust study design. This simply means collecting data in such a way as to maximise the ability to detect an effect of the highway or mitigation, should one exist. In practice, these means collecting data before and after mitigation, and to do this at sites being mitigated and at sites without mitigation. For example, measuring changes in gene flow is best done by measuring genetic diversity before the upgrade and after the upgrade, and doing this at the A8 and other nearby roads that are not being upgraded so any changes can be attributed to the work on the A8. Similarly, trying to quantify the effectiveness of fencing at reducing rates of WVC ideally requires the collection of roadkill data before and after the fences are installed at locations with fencing and locations without fencing.

As explained at the beginning of this section, monitoring and evaluation is an important part of the project and one that should be planned for, budgets set aside and implemented as early as possible in the process. If left until after the road is completed, any opportunity to collect ‘before’ data has passed, and the ability to accurately and reliably measure success has been severely curtailed.

7 LOCATION OF WILDLIFE CROSSING STRUCTURES AND FENCING

Wildlife crossing structures and fencing are proposed for areas along the alignment where the highway dissects or passes close to wildlife habitat. The specific locations are shown in Table 7.1 below and a description of each crossing in the following sections.

The following criteria were used to classify each location and are used in Table 7.1.

Importance for connectivity was derived from the Connectivity Modelling analysis conducted by UoN.

Ecological priority was determined by considering the diversity and abundance of wildlife in the area and the current and potential future extent, quality and tenure of habitat in the area

Expected use of a structure was classified as a priority for wildlife (i.e. high priority) or incidental (low priority).

Structure type describes the type and size of the structure – e.g. vegetated land bridge, bridge underpass, box culvert, canopy bridge, etc. The size of a structure is always given in metres, and describes the cross-section of the structure from the perspective of wildlife using it (H x W x L).

Structure focus describes whether the structure is being designed and constructed specifically for wildlife (i.e. dedicated wildlife crossing) or whether it is intended to function for other purposes in addition to the movement of wildlife, such as drainage or the movement of people and livestock (i.e. multi-use).

Incidental multi-use structures are essentially drainage structures or people/livestock underpasses that are slightly modified to also help some wildlife

Intentional multi-use structures are drainage structures and people/livestock underpasses that are specifically planned, designed and managed to also function effectively for wildlife. This typically means the inclusion of a culvert cell that is specifically for people and livestock to keep people and wildlife separate or building a large open span bridge and keeping people and livestock to one side.

Important considerations in determining the location and design of crossing structures were the land tenure and management considerations outlined in Section 3.4.7. These considerations focus on the long-term security of land tenure for conservation and the ability to audit the use of such land for conservation purposes. Despite being important from a wildlife conservation perspective, Marula Estate and Soysambu Conservancy are not protected in perpetuity to the same extent as the KWS land, and the number and size of WCS in these areas reflects this significant constraint. Indeed, the recent sale of land on the east side of the A8 by Soysambu, which occurred between the commencement of this project, highlights the rapid changes in land ownership and land-use in the study area.

Table 7-1. Details of wildlife crossing structures for the Project. Crossings 1 to 15 originally proposed by KWS (see Table 3.1 for preliminary suggested design) and other crossings were identified during the ESIA.

Road Section	WCS ID#	Chainage	Location	Relative importance for connectivity*	Ecological priority**	Expected use (intentional or incidental)	Structure focus (dedicated or multi-use)	Final recommendation (Width x height)
Section 1 - A8	**1**	22825	Kikuyu Escarpment Forest Reserve (Kijabe)	Medium (23.3)	High	Intentional	Dedicated	-Maintain the existing structure (10 m x5 m) for multiple use by wildlife, people, livestock -Install new 5 m x 3.5 m dedicated wildlife underpass -Add fencing, revegetation and landscaping to existing and new WCS
Section 1 - A8	**2**	~25325	Kikuyu Escarpment Forest Reserve (Kijabe)	Medium (21.6)	High	Intentional	Dedicated	-Maintain existing structure (4.5 m x 4 m) for multiple use by wildlife, people, livestock -Install new 5 m x 4.5 m dedicated wildlife underpass -Add fencing, revegetation and landscaping to existing and new WCS
Section 1 - A8	**16**	22700 to 29000	Kikuyu Escarpment Forest Reserve	NA (arboreals)	High	Intentional	Dedicated	-Install 4 canopy bridges (approx. 1 per 1.5 km of road) in this location -Precise location and design to be confirmed
Section 1 - A8	**17**	42900	Kinungi – existing waterway crossing	Very low (5.5)	Low	Incidental	Multi-use	-Maintain existing structure 2.5 m x 2.5 m -Add fencing, revegetation and landscaping to existing WCS
Section 1 - A8	**3**	53375	Naivasha East - KWSTI	Low (12.1)	High	Intentional	Dedicated	-Install new 20 m x 7 m underpass for Giraffe. -Underpass proposed to minimise noise and light effects from adjacent developments and nearby interchange. -Add fencing, revegetation and landscaping to new WCS
Section 2 - A8	**18**	59710	Existing Karati River crossing	Low (18.1)	Low	Incidental	Multi-use	-Maintain existing structure and build same structure under new carriageway with 5 m separation between two bridges -Add fencing, revegetation and landscaping to existing and new WCS
Section 2 - A8	**19**	64710	Existing Melawa River crossing	High (39.9)	Low	Incidental	Multi-use	-Maintain existing structure and build same structure under new carriageway with 5 m separation between two bridges -Add fencing, revegetation and landscaping to existing and new WCS
Section 2 - A8	**4**	69235	Marula Estate	High (38.1)	High	Incidental	Multi-use	-Maintain and extend existing 3 m x 2.5 m underpass under new carriageway. -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife

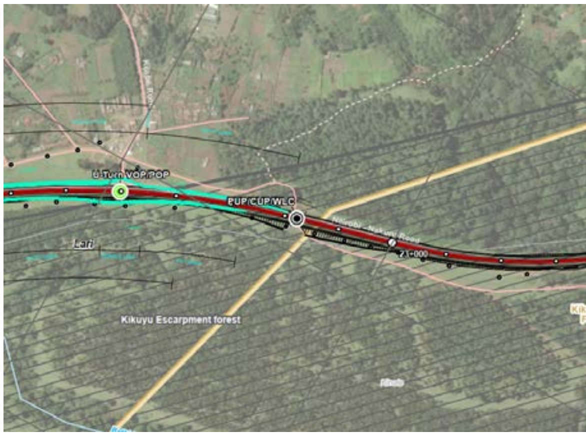
Section 2 - A8	**5a**	70220	Marula Estate	High (34.7)	High	Intentional	Multi-use	-Maintain and extend existing 5 m x 4 m underpass under new carriageway -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife
Section 2 - A8	**7**	73705	Kigio (Marula Estate)	High (35.5)	High	Intentional	Multi-use	-Maintain and extend existing 5 m x 4 m underpass under new carriageway. -Install new multi-use 7 m x 3.5 m underpass under both carriageways -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife
Section 2 - A8	**8**	76180	Gilgil River (Marula Estate)	Medium (26.3)	High	Intentional	Multi-use	-Maintain existing 3-cell culvert under existing carriageway -Install 8 m x 3.5 m underpass under new carriageway with 2 m gap between carriageways -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife
Section 2 - A8	**10**	92040 and 92250	Elmenteita-Kariandusi	Medium (24.0)	High	Intentional	Multi-use	-Maintain and extend existing 5 m x 3 m culvert at CH92040 under new carriageway -Maintain and extend twin cell 2.5 m x 2.5 m culvert at CH 92250 under new carriageway -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife
Section 2 - A8	**13**	104665	Soysambu Conservancy	Very high (82.2)	Moderate – adjacent land sold	Intentional	Multi-use	-Maintain and extend existing 5 m x 3.5 m underpass under new carriageway. -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife
Section 2 - A8	**14**	106215	Soysambu Conservancy	Very high (68.1)	Moderate – adjacent land sold but waterway retained	Intentional	Multi-use	-Maintain and extend existing 5 m x 3.5 m multi-use underpass under new carriageway. -Maintain and extend existing twin cell drainage culvert (3 m x 2.5 m) under new carriageway -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife
Section 4 - A8	**21**	153820	Existing waterway crossing	Very low (0)	Moderate – waterway through private land	Incidental	Multi-use	-Maintain and extend existing 15 m x 4 m bridge on waterway under new carriageway. -Assess hydrology requirements and if feasible, install ledge/shelf on one side of bridge for pedestrians and 2nd ledge or shelf on opposite side for wildlife -Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife

Section 4 - A8	**23**	166600 to 168200	Koibatek forest in Mount Londiani Forest Reserve.	Very low (0)	High	Intentional	Dedicated	-Install new 10 m x 5 m underpass for wildlife, specifically elephants -Add/re-align fencing if required, revegetation and landscaping to new WCS to enhance use by wildlife
Section 4 - A8	**24**	162600 - 168200	Koibatek forest in Mount Londiani Forest Reserve.	NA	High	Intentional	Dedicated	-Install 4 canopy bridges (approx. 1 per 1.5 km of road) in this location -Precise location and design to be confirmed
Section 5 - A8South	**29**	51500	Corridor between KWSTI and Lake Naivasha	Low (17.8)	Very high	Intentional	Dedicated	-Install 40 m wide vegetated landbridge -Install noise and light walls on edge of landbridge and on approaches to landbridge. -Add/re-align fencing if required, revegetation and landscaping to new WCS to enhance use by wildlife

* Sum of movement probability index using favorable scenario Zebra, Giraffe, Buffalo

** Based on land tenure, habitat, wildlife

7.1 WCS 1: CH22825



Context

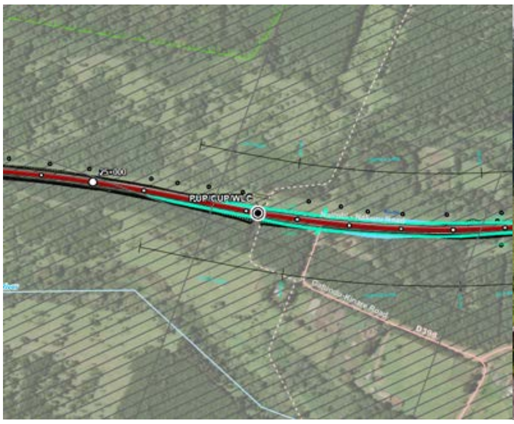
Existing structure is a 10 m wide x 5 m high underpass for livestock, pedestrians and farm/forestry machinery where road is raised on extensive fill. A8 passes through Kikuyu Escarpment forest which is a large area of forest to the east and west of the road with extensive wildlife populations.

Recommendation

Maintain existing underpass for people, livestock, machinery and incidental wildlife use. Install dedicated box culvert 5 m wide x 3.5 m tall for wildlife a minimum of 250 m from the multi-use underpass.

Install wildlife fencing from ~CH22400 to CH29000. Undertake landscaping and revegetation to enhance use by wildlife.

7.2 WCS 2: CH25325





Context

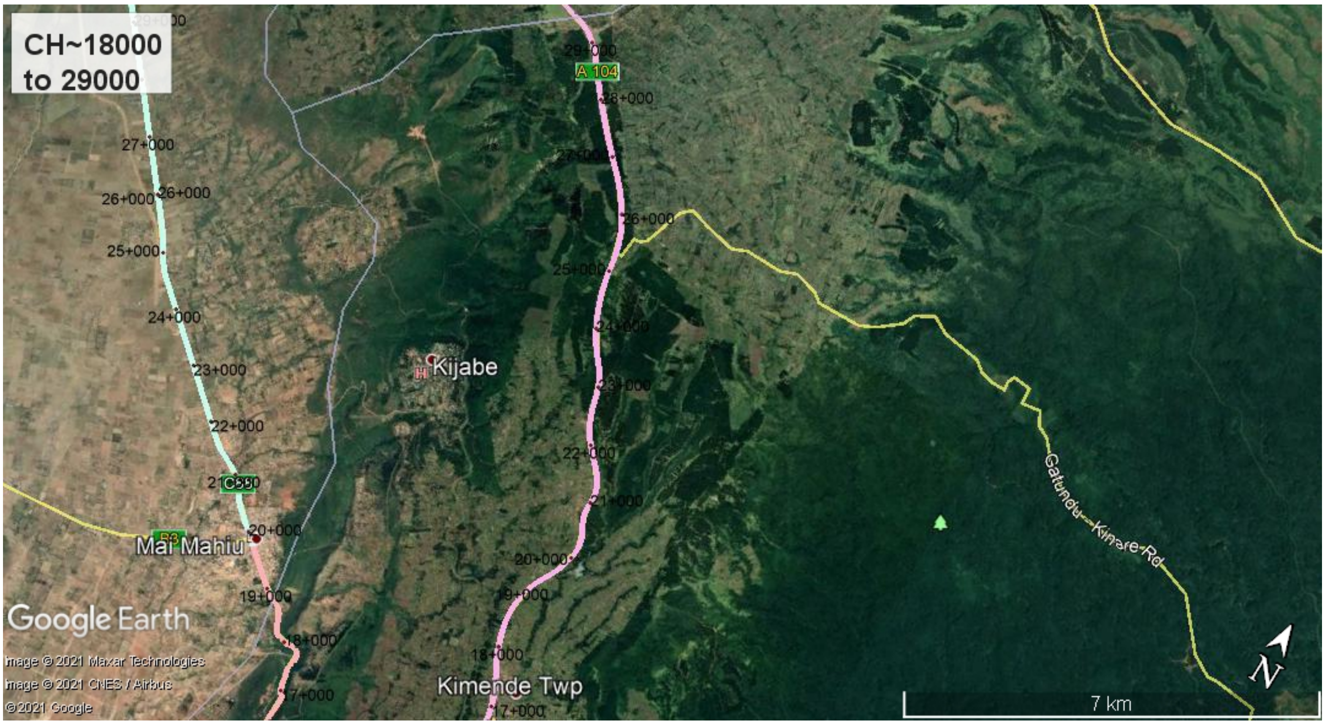
Existing structure is a single cell culvert (4.5 m wide x 4 m tall) for people, livestock and machinery where road is on extensive fill. A8 passes through Kikuyu Escarpment forest which is a large area of forest to the east and west of the road with extensive wildlife populations.

Recommendation

Maintain existing underpass for people, livestock, machinery and incidental wildlife use. Install dedicated box culvert 5 m wide x 4.5 m tall for wildlife a minimum of 250 m from the multi-use underpass.

Install wildlife fencing from ~CH22400 to CH29000. Undertake landscaping and revegetation to enhance use by wildlife.

7.3 WCS 16: CH ~22700 – 29000



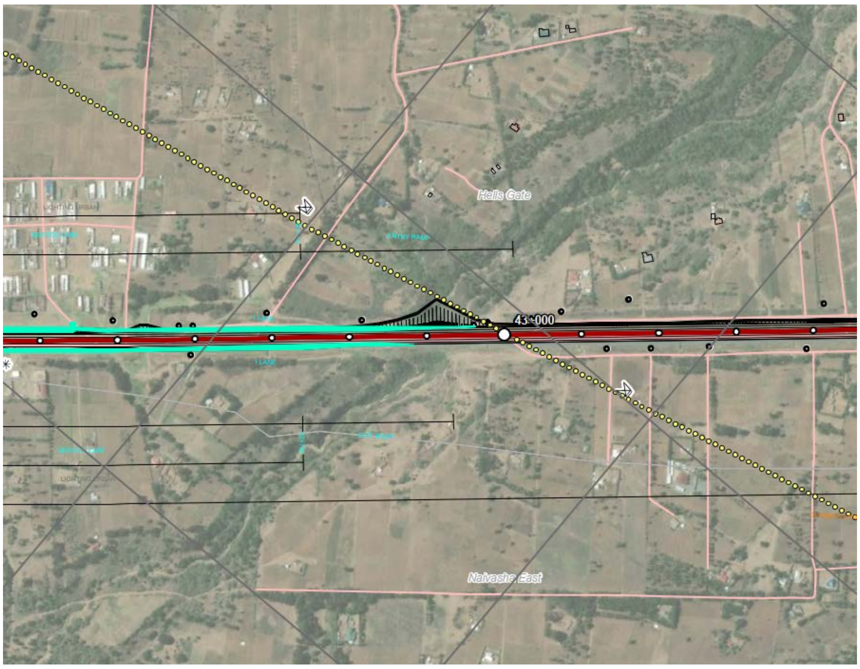
Context

A8 passes through Kikuyu Escarpment Forest Reserve with connections to extensive areas of forest to east and west of A8.

Recommendations

Install four canopy bridges (approximately one every 1.5 km of highway) for arboreal species of wildlife through the Kikuyu Escarpment Forest Reserve. The confirmation of the exact location and design is dependent upon confirmation of suitable target species of wildlife in the forest, sufficiently large trees close to the highway and the development and testing of approved designs. These four canopy bridges may be moved to elsewhere on A8 or A8South.

7.4 WCS 17: CH42900



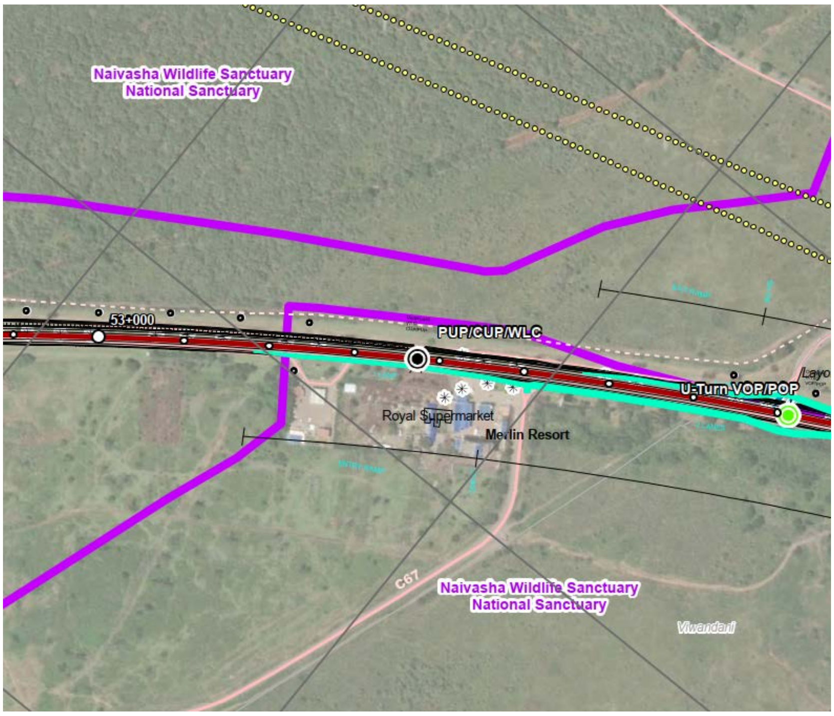
Context

Waterway crossing through 2.5m x 2.5m culvert under A8 that supports wooded vegetation and provides landscape linkage through private agricultural and pastoral land.

Recommendation

Maintain existing and extend under new carriageway as incidental multi-use structure for occasional water flow and wildlife. Add fencing, landscaping and revegetation to enhance use by wildlife.

7.5 WCS3: CH53375



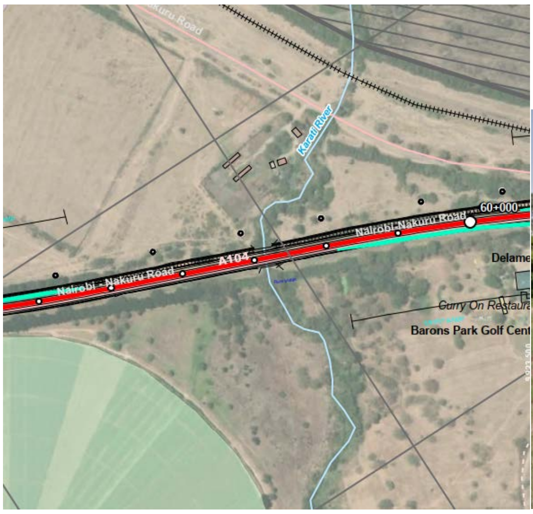
Context

Crossing across A8 to connect Naivasha Wildlife Sanctuary and the Kenya Wildlife Service Training Institute (KWSTI). Important linkage from Lake Naivasha across A8South and A8 to the east. Includes large areas of secure conservation land and extensive wildlife populations, including Giraffe. Existing powerlines, petrol station, hotel and streetlighting, and new interchange proposed for CH 53800.

Recommendations

Install large underpass 20 m wide x 7 m tall for Giraffe and other species. Maintain and enhance fencing if required, and use noise and light walls above underpass and on approaches to underpass to protect Giraffe from disturbance. Adjust position of street lighting if it interferes with underpass. Add fencing, landscaping and revegetation to enhance use by wildlife.

7.6 WCS 18: CH 59710





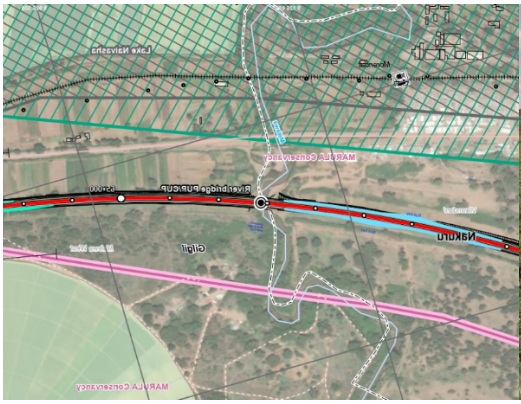

Context

Karati River crossing under A8 that supports wooded vegetation and provides landscape linkage through agricultural and pastoral land.

Recommendation

Replicate existing structure under new carriageway with 5 m separation between carriageways to allow sunlight and rain to penetrate and support natural vegetation growth. Separation also reduces tunnel effect for wildlife. Add fencing, landscaping and revegetation to enhance use by wildlife.

7.7 WCS 19: CH64710



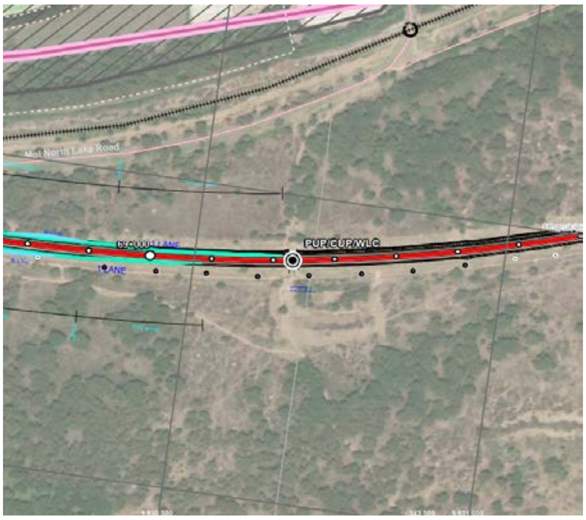
Context

Melawa River crossing under A8 via a bridge that supports wooded vegetation and provides landscape linkage through agricultural and pastoral land.

Recommendation

Replicate existing structure under new carriageway with 5 m separation between carriageways to allow sunlight and rain to penetrate and support natural vegetation growth. Separation also reduces tunnel effect for wildlife. Add fencing, landscaping and revegetation to enhance use by wildlife.

7.8 WCS 4: CH69235



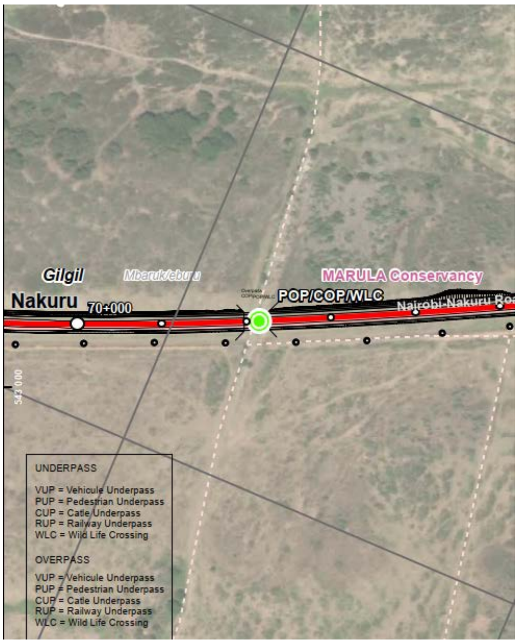
Context

In Marula Estate, A8 is on fill and this location has an existing underpass 3 m wide x 2.5 m tall. Existing fence and locked gate. Currently used by livestock, pedestrians and farming.

Recommendation

Low feasibility location due to private land on both sides of road. Extend existing underpass with same dimensions under new carriageway. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance incidental use by wildlife.

7.9 WCS 5A: CH70220



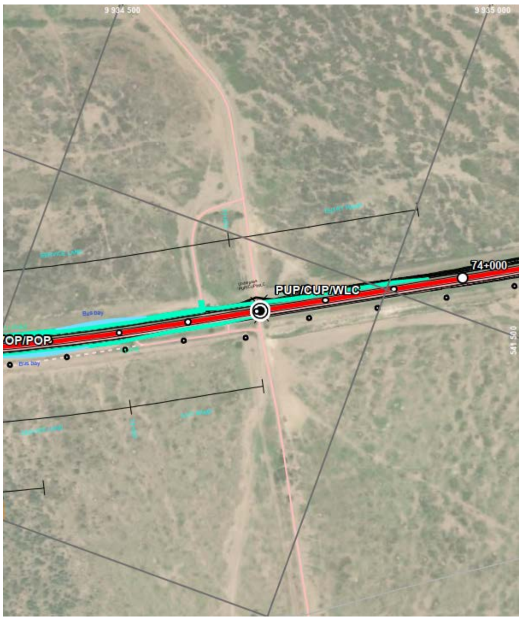
Context

In Marula Estate, A8 is on fill and this location has an existing underpass 5 m wide x 4 m tall, currently used for livestock, pedestrians and farming. Existing fencing and gate on west side of road.

Recommendation

Low feasibility location due to private land on both sides of road. Extend existing underpass with same dimensions under new carriageway. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.10 WCS7: CH73705



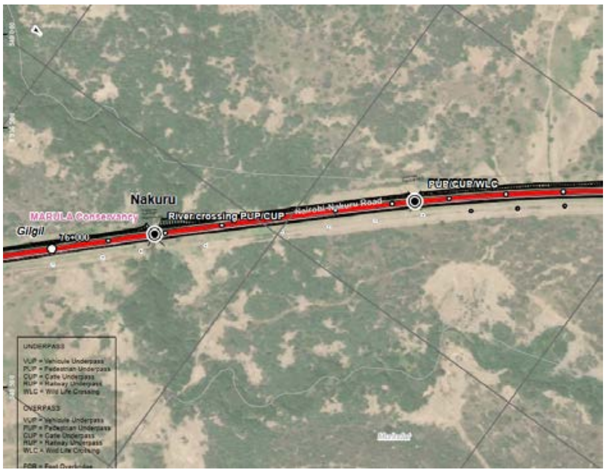
Context

In Marula Estate, A8 is on fill and this location has an existing underpass 5 m wide x 4 m tall, currently used for livestock, pedestrians and farming. Existing fencing and gate being built on west side of road.

Recommendation

Low feasibility for dedicated WCS due to private land on both sides of road. Existing underpass to be extended under new carriageway and new multi-use underpass 7 m wide x 3.5 m tall to be installed for wildlife, livestock, pedestrians and farm machinery. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.11 WCS8: CH76180



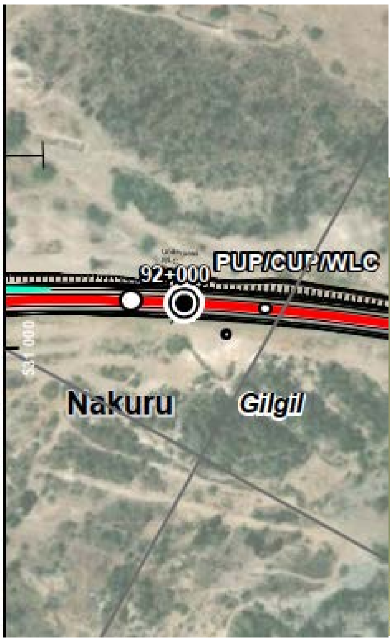
Context

In Marula Estate, A8 is on fill and this location has an existing 3-cell culvert for Gil Gil river crossing. Outer cells 3 m x 3 m and middle cell 3 m wide x 5 m tall. Currently used for livestock, pedestrians and farming. Existing on west side of road.

Recommendation

Low feasibility location due to private land on both sides of road. Maintain existing underpass and build 8 m x 3.5 m underpass under new carriageway that is more open for wildlife with 2 m separation between two carriageways. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.12 WCS 10: CH 92040 AND CH 92250



Context

A8 is on fill in this area and there is an existing single cell multi-use culvert (at CH 92040) that is 5 m wide x 3 m high and a twin cell culvert (at CH 92250) for drainage that is 2.5 m x 2.5m.

Recommendation

Extend existing underpass at CH 92040 and CH 92250 with same dimensions under new carriageway. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.13 WCS13: CH104665

Context

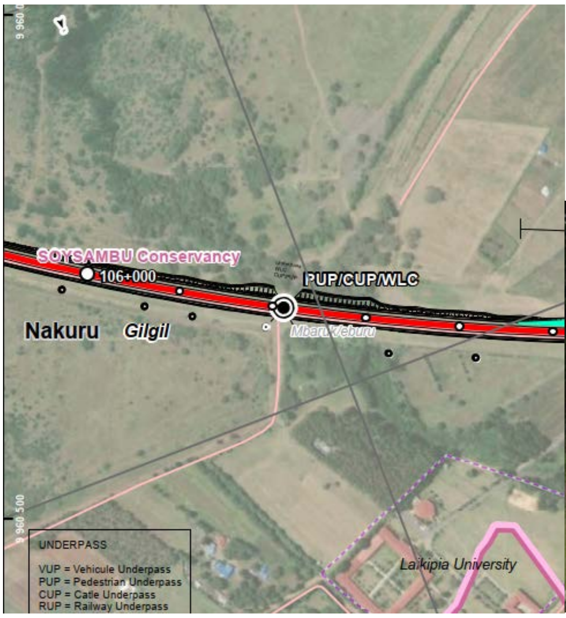
A8 is on fill in this location with existing 5 m wide x 3.5 m tall culvert for livestock, pedestrians and farm use by Soysambu conservancy.

Recommendation

Low feasibility location due to private land on both sides of road and sale of land on east side of road for intensive private development.

Extend existing underpass with same dimensions under new carriageway. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.14 WCS14: CH106215



Context

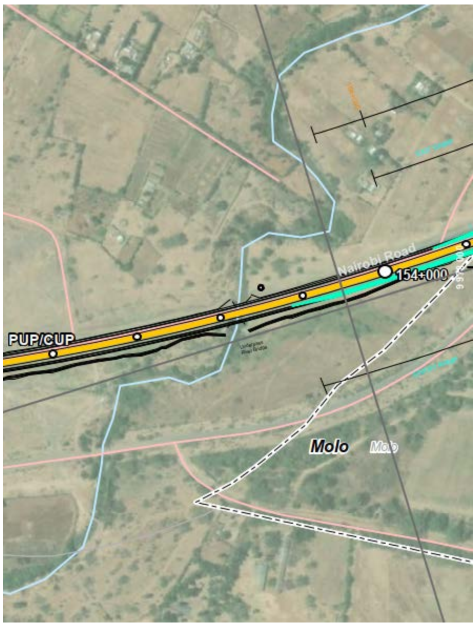
A8 on extensive fill and large culvert (5 m wide x 3.5 m tall) for livestock, vehicles and pedestrians, plus twin cell culvert (3 m wide x 2.5 m tall) at waterway. Both sides of road fenced. Land on east side of A8 at this location has been sold and will be developed. This waterway has been retained a spart of Soysambu conservancy.

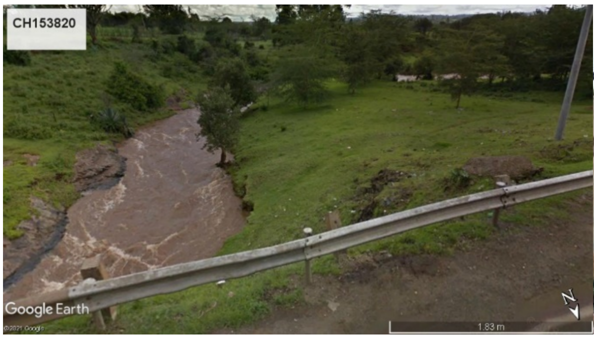
Recommendation

Low feasibility location due to private land on both sides of road and sale of land on east side of road for intensive private development.

Extend existing underpasses with same dimensions under new carriageway. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.15 WCS 21: CH153820





Context

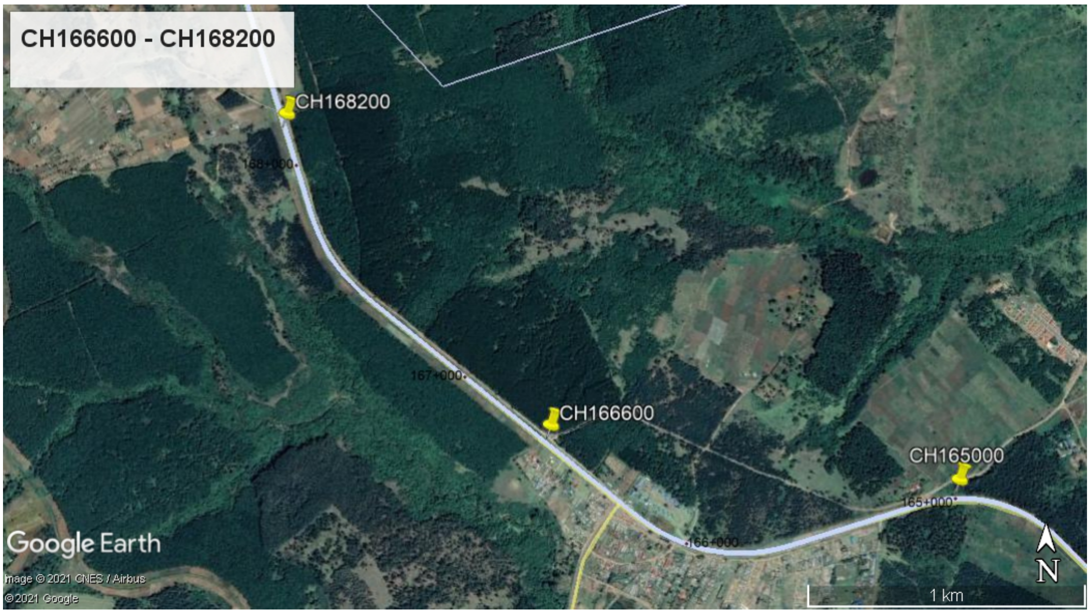
A8 is on extensive fill and existing crossing (15 m wide x 4 m tall bridge) of waterway passing through agricultural land. School nearby and request for pedestrian crossing at this structure for school children.

Recommendation

Maintain and extend existing crossing under new carriageway. Undertake hydrological study and if feasible, install ledge or shelf for pedestrian use and second ledge or shelf on opposite side for wildlife use.

Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

7.16 WCS23: CH166600 TO CH168200





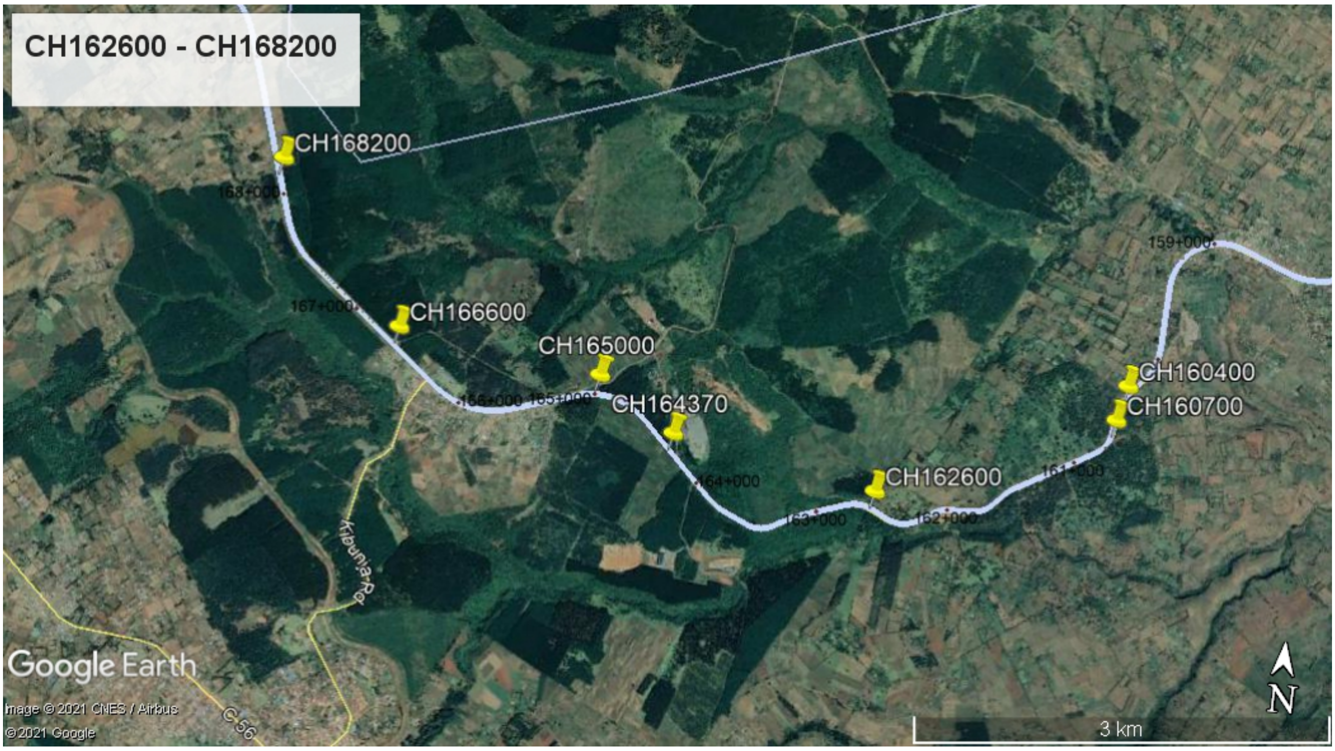
Context

A8 passes through Koibatek Forest in Mount Londiani Forest Reserve, an extensive area of potential habitat which has recently had elephant sightings. The forest includes a mix of tree species and some commercial harvesting. The A8 is either at grade or in cuttings or on the side of a hill through much of this area.

Recommendation

Install a 10 m wide x 5 m high underpass for wildlife, specifically elephants. Install fencing on both sides of the road to funnel elephants and other wildlife to the underpass. Undertake revegetation and landscaping to WCS to enhance use by wildlife.

7.17 WCS24: CH162600 – CH168200



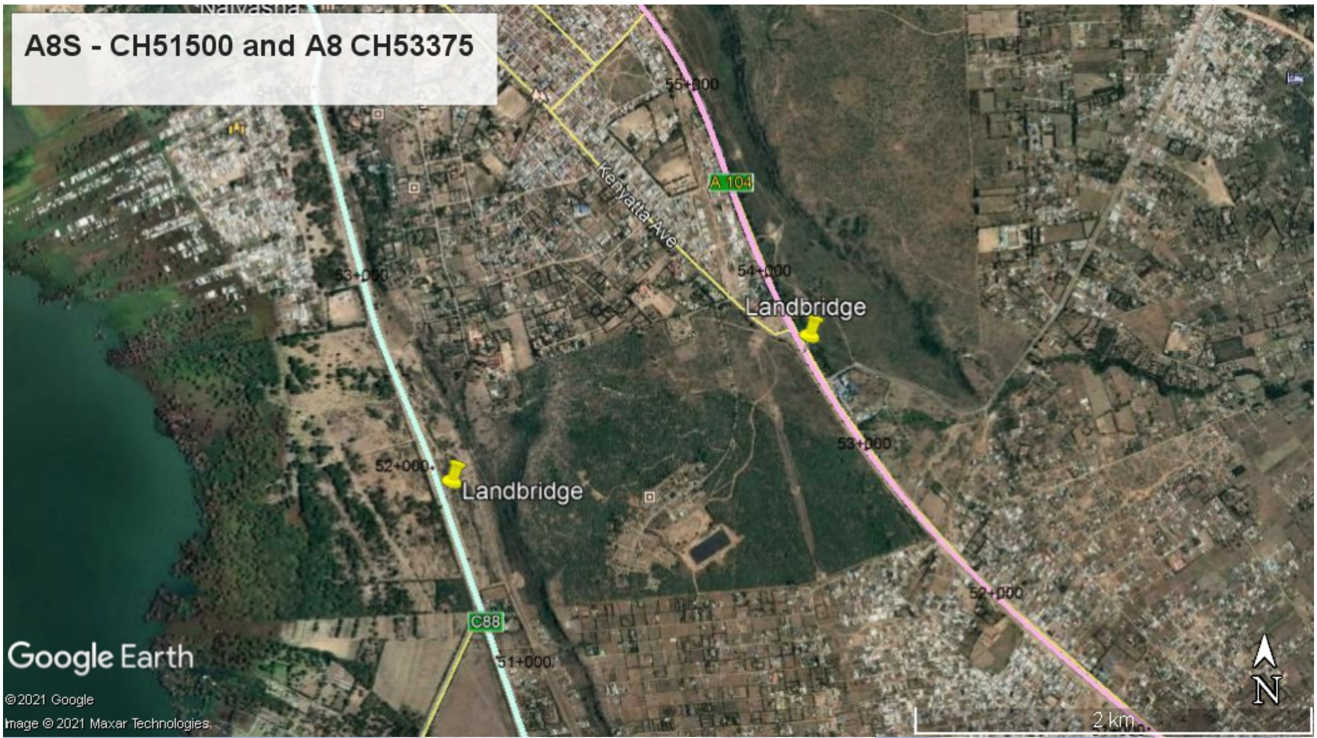
Context

A8 passes through Koibatek Forest in Mount Londiani Forest Reserve, an extensive area of potential habitat. The forest includes a mix of tree species and commercial harvesting. The A8 is either at grade or in cuttings or on the side of a hill through much of this area.

Recommendations

Install four canopy bridges (approximately one every 1.5 km of highway) for arboreal species of wildlife through Mount Londiani Forest Reserve. The confirmation of the exact location and design is dependent upon confirmation of suitable target species of wildlife in the forest, sufficiently large trees close to the highway and the development and testing of approved designs. These four canopy bridges may be moved to elsewhere on A8 or A8South.

7.18 WCS29: CH51500 (A8 SOUTH)



Context

A8 South passes through an active wildlife dispersal corridor from Lake Naivasha to the KWSTI with numerous roadkills. A8 is mostly at grade through this location.

Recommendation

Install a 40 m wide vegetated landbridge to accommodate all species in the area, including Giraffe, Buffalo, Eland, Zebra etc. This landbridge on A8South is critical to the function of the underpass (WCS3) on A8. Install noise and light walls on edge of landbridge and on approaches to land bridge. Add/re-align fencing if required, revegetation and landscaping to existing and new WCS to enhance use by wildlife.

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8 APPENDIX 1. ANECDOTAL RECORDS OF WILDLIFE-VEHICLE COLLISSIONS FROM NATIONAL MUSEUM OF KENYA

PROJECT AREA	SPECIES IMPACTED (COMMON NAME)		COMMENTS
Limuru/Upland/Rironi area	Monkeys (vervet and/or Sykes')	*Cercopithecus spp*	Commonly crashed by vehicles
	Northern Greater Galago	*Otolemur garnettii*	Rare
	Maned Rat	*Lophiomys imhausi*	Commonly killed
	Horseshoe Bat	*Rhinolophus spp*	Rare
	Large-eared free-tailed bat	*Otomops martiensseni*	Very rare
	Four-toed hedgehog	*Atelerix albiventris*	Very commonly killed
Karai-Naivasha	Mole Rats	*Tachyoryctes spp*	Commonly killed
	Scrub Hare	*Lepus saxitilis*	Commonly killed
	Short-snouted elephant shrew	*Elephantalus brachyrynchus*	Rare
Gilgil/Elmentaita	Olive Baboon	*Papio anubis*	Very commonly killed
	Common warthog	*Pharcocherus africanus*	Rare
	Plains Zebra	*Equus quagga*	Common
	Common eland	*Taurotragus oryx*	Very rare
	Aardvark	*Orycteropus afer*	Commonly killed
	Vervet monkey	*Chlorocebus pygerythrus*	Common
	East African springhare	*Pedestes surdaster*	Rare but easily isolated by road
	Silverbacked jackal	*Canis mesomelas*	Commonly killed
	African striped weasel	*Poecilogale albinucha*	Commonly killed as they scavenge
	Leopard and Lion	*Panthera spp*	Leopard commoner than Lion

	Cheetah	*Acinonyx jubatus*	Rare
	Serval	*Leptailurus serval*	Fairly common
	African civet	*Civettictis civetta*	Common as they scavenge
	Spotted hyena	*Crocuta crocuta*	Very commonly killed as they scavenge on road kills
	White-tailed mongoose	*Ichneumia albicauda*	Commonly killed
Salgaa-Sachangwan-mau summit	East African mole-rat	*Tachyoryctes naivashae (splendens)*	Endemic; commonly killed when dispersing on land
	Kerbis Peterhans's wood mouse	*Hylomyscus kerbispeterhansi*	Endemic: rare
	Small-footed forest mouse	*Hylomyscus endorobae*	Rare